Technical Report 1031

Training Strategies for Tactical Pattern Recognition

Susan C. Fischer and James Geiwetz
Anacapa Sciences Inc.

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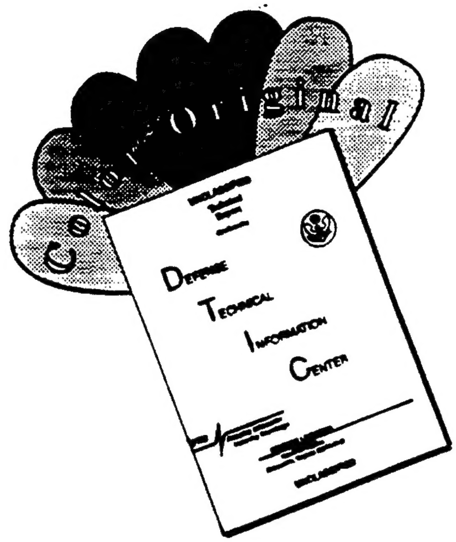

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Training Strategies for Tactical Pattern Recognition

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Foreword

The Fort Leavenworth Research Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research to enhance the Battle Command capabilities of Army leaders. The research focus is on the human dimension of combat: How to develop better leaders through innovative leader education, development and training

Pattern recognition is a critical skill for effective Battle Command as commanders must be able to quickly interpret visual stimuli in the form of maps and overlays. Army leaders are provided with the rules and methods of effective command, but not direct instruction in interpreting and using battlefield patterns. Expertise in these skills develops over years of experience and study.

The present research was conducted to evaluate the effectiveness of pattern recognition training on Army officers' knowledge and skill with regard to tactical terrain situation assessment. The results indicate that it may be possible to speed up the development of important skills by providing innovative training such as the model investigated in this research.

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ACKNOWLEDGMENTS

This project benefited greatly from the contributions of a number of individuals. We are deeply indebted to three subject matter experts who were instrumental in developing the pattern recognition training. Retired Lieutenant Colonels Carl Bierbaum, Richard Fuller, and Thomas Savoie each shared invaluable knowledge and experience that served to guide the focus and content of the training.

We would also like to express our gratitude to the Professors of Military Science at the four universities that participated in this research, Lieutenant Colonel Cole, Major Schumacher, Captain Reilly, and Captain Holland. Their agreement to implement the pattern recognition training in their programs was critical to the project; without their assistance this research could not have been conducted. We would also like to thank the Military Science students in both the experimental and control groups for their conscientious effort. The individuals in the experimental group devoted their own time to study the material in the pattern recognition course. Individuals in both groups then participated in a somewhat lengthy testing session. We are very grateful for their participation. The officers of Fort Bragg also deserve our thanks for participating in their testing session.

We are also indebted to our fellow Anacapa Sciences staff members, Paul Blowers, Liane Romero, and Mike McAnulty who capably provided assistance in developing the pattern recognition training, conducting the knowledge elicitation sessions, reviewing materials, developing measurement instruments, gathering data, and conducting the analyses.

Finally, we'd like to thank the ARI Field Unit at Fort Leavenworth, Kansas for their guidance and support through each phase of this project. We are grateful for the open forum they provided for the discussion of pattern recognition issues in Battle Command. This work has benefited greatly from the contributions of Drs. S. Delane Keene, Stan Halpin, Jon Fallesin, Jim Lussier, Rex Michel, Bob Solick, and Doug Spiegel.

TRAINING STRATEGIES FOR TACTICAL PATTERN RECOGNITION

EXECUTIVE SUMMARY

Requirement:

Pattern recognition is likely to be a critical skill for effective Battle Command. Commanders must be able to interpret visual stimuli in the form of maps and overlays. Battle Command involves the comprehension of recognizable patterns such as enemy deployment patterns, enemy patterns of activity, and terrain features. In summary, situation assessment is likely to involve the recognition of tactical patterns. A review of the Army's formal curriculum reveals that Army officers do not receive direct training in battlefield patterns. They are provided with the rules and methods of effective command, but not direct instruction in interpreting and using battlefield patterns. If these skills are developed, it is likely that they are an indirect byproduct of job experience and independent study, which can take years.

The purpose of this research was to evaluate the effectiveness of pattern recognition training on Army officers' knowledge and skill with regard to tactical terrain situation assessment. The general idea was that skilled performance, which normally takes years to develop, might be taught in 8 to 40 hours of direct pattern recognition training.

Procedure:

Four hypotheses were tested in this research: (1) terrain pattern recognition training increases the amount of information learned about terrain features compared to traditional Army training methods; (2) terrain pattern recognition training increases retention of information about terrain features; (3) terrain pattern recognition training produces better recognition of novel terrain features; and (4) individual differences in cognitive style and spatial ability mediate students' ability to profit from terrain pattern recognition training.

Eighty-three college Military Science students participated in this research. Four year groups (MS1 - MS4) from the Reserve Officer Training Corps (ROTC) populations at four universities participated. Forty-seven of these students were assigned to the experimental group of subjects, who received the pattern recognition training. Thirty-six students were assigned to the control group, who received only the standard Army ROTC training. A

sample of 14 Army Captains also participated in the study, forming the experienced group of subjects for comparison. Students were randomly assigned to the experimental and control groups.

The pattern recognition training was initiated with the distribution of course materials to each student in the experimental group. Students were permitted two weeks to study the material.

Evaluation of the effectiveness of the training was based on four measurement instruments designed and developed for this project. Two measures of individual differences in cognitive style and spatial ability were also administered. The testing was conducted in one session at each university immediately following the two week study period. Students from the control and experimental groups were tested together in the same testing session. A small sample of 12 subjects were retested nine months following the original testing period to determine if the skills they had obtained were retained.

Findings:

The results of this study revealed that pattern recognition training increases learning compared to traditional ROTC training methods. Students who received the pattern recognition training scored better on three of the four outcome measures than students who received traditional training. Moreover, the students who received the pattern recognition training performed at the same level as the group of Army Captains. Therefore, the training effectively raised ROTC student terrain pattern knowledge to a level comparable to Army Captains. The results of the retest session with the small sample of subjects was mixed. The results were also mixed regarding the degree to which pattern recognition training produces better recognition of novel stimuli. On one set of subscales, students in the experimental and control groups performed at the same level. In another subscale that incorporated novel items, students who received the pattern recognition training were better able to recognize the patterns. Cognitive style and spatial ability did not interact with training. Pattern recognition training appears to be equally effective for all types and levels of cognitive style and spatial ability tested in this research.

Utilization of Findings:

To prepare Army officers to meet command responsibilities, Army training comprises comprehensive instruction in principles of warfare, enemy and friendly battlefield doctrine, and methods of effective command, as well as practice in applying this knowledge through simulations and field

exercises. The majority of direct training that an officer receives in the classroom is in the form of rules, doctrine, and other significant information. Because of their high expense, exposure to simulations and field exercises is much more limited and probably lower than optimal. It may be possible to speed up the development of important skills by providing innovative training such as the model investigated in this research. Further research is necessary to explore possible applications in other content areas.

TRAINING STRATEGIES FOR TACTICAL PATTERN RECOGNITION

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Introduction

The U.S. Army's decentralized command structure in AirLand Battle doctrine gives individual tactical commanders great responsibility. Notwithstanding the significant roles each staff member plays, the commander himself must be sufficiently cognizant of the battlefield situation to provide his staff with initial and continuing guidance. Moreover, commanders must be able to decide quickly how to respond to ever changing, dynamic conditions on the battlefield. It is often the case that commanders have to rely on intuition when determining how to respond to a particular situation, especially when operating under time pressure or uncertainty. According to *The Command Estimate* (CGSC ST 100-9, 1989), the key to effective decision making is the estimate of the situation, which is accomplished and revised on a continuous basis throughout planning and execution stages.

To prepare Army officers to meet command responsibilities, Army training comprises comprehensive instruction in principles of warfare, enemy and friendly battlefield doctrine, and methods of effective command, as well as practice in applying this knowledge through simulations and field exercises. The majority of direct training that an officer receives in the classroom is in the form of rules, doctrine, and other significant information. Because of their high expense, exposure to simulations and field exercises is much more limited and probably lower than optimal. Army officers also acquire a large amount of knowledge through experiences at duty assignments, the sources of which might be direct instruction given by their commanding officer, their experiences on the job, or their own independent study.

As a result of many years of direct training, field exercises, on-the-job experiences, and independent study, officers develop considerable Battle Command expertise. Some commanders develop extraordinary skills in interpreting battlefield situations and developing appropriate courses of action. Some seem to almost immediately grasp the militarily significant features of a battlefield situation, and are able to use this information to make effective plans and provide guidance to their staffs. Apparently, this expertise develops over years of experience because it is typically found in high ranking individuals who have devoted years of study to the art of warfare. The length of study necessary to develop Battle Command expertise is consistent with current research regarding the development of expertise in other domains such as chess, physics, some motor skills, music, writing, and medical diagnosis (Chi, Glaser, & Farr, 1988; Ericsson & Smith, 1991). For example, it has been estimated that chess players must practice 10 years or more to attain an international level of performance (Simon & Chase, 1973) and others have found consistent support for the requirement of 10 years of intensive preparation for many domains (Ericsson & Crutcher, 1990).

Commanders' expertise may be due to the accumulation of knowledge in the form of *patterns*. Research conducted over the past 20 years has shown that skilled pattern recognition is a hallmark of expertise. For example, expert programmers can reproduce *meaningful* patterns of program code better than code that does not follow accepted programming rules (Soloway, Adelson & Ehrlich, 1988). Master chess players

have better recall for chess pieces that are placed in meaningful patterns on a chess board than for random patterns of chess pieces (Chase & Simon, 1973; de Groot, 1966). Experts in reading circuit diagrams, reading architectural plans, and interpreting x-ray plates have all been shown to possess superior skill in perceiving meaningful patterns in their respective domains (Akin, 1980; Egan & Schwartz, 1979; Lesgold, Rubinson, Feltovich, Glaser, Klopfet and Wang 1988). Therefore, it seems reasonable to hypothesize that at least one component of Battle Command expertise is the ability to perceive significant battlefield patterns.

As is true for chess players, architects, electronics technicians, x-ray technicians, and others, there are perceptual and spatial components to the Army commander's domain. Their work entails the use of maps that represent geographic areas with limited spatial extent in which enemy and friendly troops are positioned. They must recognize, interpret, and utilize meaningful battlefield patterns, many of which are bound by geography. For example, enemy unit patterns of activity are of concern depending on their geographic location in relation to the commander's sector of responsibility. Enemy deployment patterns are similarly bound by space and geography. Thirdly, the terrain itself forms militarily meaningful patterns that an Army commander must recognize, evaluate, and utilize in his plans. Therefore, it is likely that at least one element of Battle Command expertise is the skilled perception of militarily significant battlefield patterns.

A review of the Army's formal curriculum reveals that Army officers do not receive direct training in battlefield patterns. As noted above, current Army instruction delivers information to the student regarding the rules and methods of effective command. What Army training does *not* provide is direct instruction in the recognition, interpretation, and utilization of common battlefield patterns. Rather than obtaining pattern recognition skills through formal education and training, officers apparently develop these perceptual and analytical skills through years of experience and independent study. Unfortunately, relying on random job experiences and self motivated study does not ensure the development of these skills.

It may be possible to facilitate the development of important pattern recognition skills by providing innovative training in the identification and use of common battlefield patterns. Formal pattern recognition training might engender knowledge and skills that officers currently might, or might not, develop through on-the-job experiences and independent study. For example, improvement in situation assessment might be readily and efficiently achieved through a pattern recognition course. Prospective commanders could learn to identify the most militarily significant patterns in a situation, which could ultimately improve their estimate of the battlefield. Pattern recognition training might also increase the speed at which commanders evaluate a situation, which would be beneficial in cases where little time was available for forming plans. The consistent pairing of patterns with appropriate responses could assist a commander in developing a readily accessible pattern knowledge base. Later, when confronted with a situation requiring an expert tactical decision, the commander could draw on his pattern knowledge base to formulate a rapid and effective course of action.

The general purpose of this project was to determine whether formal instruction in tactical pattern recognition is an effective pedagogic tool for training Army officers. As part of the project, a pattern recognition course was developed, refined, and evaluated. In this report we provide a description of the course's development and content. We also report a study that was designed to determine whether pattern recognition training would provide greater learning than current Army training. The remaining sections of the introduction to this report are devoted to a review of research findings that are relevant to the present study. We first present a discussion of current knowledge about the development of expertise. The second area covered involves relevant empirical and theoretical issues in pattern recognition, and the final topic area covers training as it relates to pattern recognition. We also discuss the particular relevance of each of the three research areas to the purposes of this project.

Background

The Development of Expertise. The investigation of outstanding performance has a long history in psychological research. Early theoretical accounts attributed superior knowledge and abilities to inherited characteristics (e.g., Galton, 1869). This theoretical position and research tradition has continued throughout this century and remains a popular interest in psychology (e.g., Guilford, 1967; Hunt, 1980; Sternberg, 1982). However, accounts of superior performance based on stable inherited characteristics is often inadequate to account for variation in outstanding performance (Ericsson, & Smith, 1991), prompting researchers in the early 1970s to turn to accounts based on acquired characteristics. The research literature base that has resulted from this turn to acquired characteristics is often termed studies of "expert/novice differences" or simply "expertise".

Perhaps the most well known research of acquired expertise comes from studies of chess masters (de Groot, 1978; Chase & Simon, 1973). In fact, the early work with chess experts has provided the seminal methodological paradigms and theoretical positions for many subsequent investigations of expertise in a host of other domains. Expertise has been studied in such divergent areas as motor skills (e.g., typewriting, sports, dance), physics, medical diagnosis, computer programming, music, literature, mental processing (memory and calculation) and judicial judgment, among others.

What general conclusions, if any, can be drawn from the past 20 years of research on acquired skill? What does it mean to be an expert? Glaser & Chi (1988) provide a concise summary of the research as indicated by the characteristics that experts exhibit, which are listed below.

1. Experts excel mainly in their own domains; skills tend not to transfer to other domains.
2. Experts perceive large meaningful patterns in their domain, which reflects a superior knowledge base.
3. Experts are fast and accurate performers.

4. Experts have better short- and long-term memory for content in their domain of expertise; they tend to chunk information into larger units and free up mental resources by automating portions of their skills.
5. Experts represent problems at a deeper level; experts' conceptual knowledge is organized semantically or by principles.
6. Experts spend a lot of time analyzing a problem.
7. Experts have strong self-monitoring skills; their metacognitive skills are highly developed in their domain of expertise.

The present research is primarily concerned with the second characteristic of expertise: "Experts perceive large meaningful patterns in their domain, which reflects a superior knowledge base." This assertion has received considerable empirical support in a wide variety of domains. For example, chess experts' and novices' ability to reproduce briefly presented, random patterns of chess pieces are uniformly poor. However, experts are able to provide almost perfect reproductions of sensible chess board patterns (Chase & Simon, 1973). The high level of performance exhibited by chess experts is apparently not due to a general superiority in memory. Rather, it is specific to the domain of chess and is related to the perception of meaningful patterns and relations among chess pieces. Similarly, studies of expert and novice computer programmers have shown that experts perform better when asked to provide missing code for programs that follow accepted patterns, or programming rules. However, they perform at the same level as their less experienced counterparts when the programs violate programming planning patterns (Soloway, Adelson, & Ehrlich, 1988). Superior memory for domain specific patterns has also been shown in studies of music savants. Recall for tonal sequences and chord progressions are high for patterns that follow Western scales, but are poor for unfamiliar sequences that violate Western musical conventions (Charness, Clifton & MacDonald, 1988; Sloboda, Hermelin, & O'Connor, 1985). Although savants appear to process information in a fundamentally different way than their "normal" expert counterparts, these studies indicate that their performance is also dependent on the recognition and retrieval of domain specific meaningful patterns. Studies of skilled ballet dancers have shown that memory for dance sequences is pattern dependent. When presented with dance sequences that are consistent with conventional ballet patterns, professional dancers exhibited better recall than less experienced dancers. However, when presented with random sequences of steps, they performed at the same level as the novices (Starkes, Deakin, Lindley, & Crisp, 1987). It is interesting that a similar study of modern dancers, who must memorize random sequences of dance steps, failed to produce the effect of pattern or structure found with ballet dancers (Allard & Starkes, 1991).

The key role of pattern recognition in expertise is also acknowledged in theoretical accounts of outstanding performance. For example, Gardner (1983) has proposed that critical individual differences in ability could be discerned from a test in which "individuals were given the opportunity to learn to recognize certain patterns and were tested on their capacities to remember these from one day to the next."

This position is based on the premise that expertise is the result of an individual's potential for high achievement and the capacity to rapidly learn material. Gardner states that an "individual so blessed [with such talent] does not merely have an easy time learning new patterns; he learns them so readily that it is virtually impossible for him to forget them. "

Pattern recognition skills are also acknowledged as key elements of expertise in theories that point to the acquisition of skills as the source of individual differences in performance (Ericsson and Charness, 1994). Ericsson and Charness deny the importance of inherited talent and ability, and argue that expertise is the *acquisition* of complex skills and physiological adaptations that are brought about by structured learning and effortful adaptation. In their view, skilled perception and memory are "acquired to meet specific demands of encoding and accessibility in specific activities in a given domain". Although they point to a different causal source of performance variation than does Gardner (1983), they also view pattern recognition as a component of expertise.

Skilled pattern recognition is only one information processing skill that experts may develop. Depending on the domain, the development of expertise may also involve increasing the knowledge base, developing better processing procedures, or a reconstruction of knowledge. Experts' use of a larger and fundamentally different knowledge base is evident in research that shows that they see and represent problems at a deeper level than novices. Experts in physics, for example, apparently organize their knowledge of physics problems according to principles of mechanics, whereas novices' organization is based on the literal objects stated in the problem description (Chi, Feltovich, & Glaser, 1981). Another example of the development of a variety of information processing skills coincident with the development of expertise comes from research conducted on expert X-ray diagnosticians. Although one might expect that pattern recognition determines expertise in radiology, research indicates that performance is driven by schema selection (Lesgold et al., 1988). In the initial phase of diagnosis, the expert selects a schema that must satisfy certain criteria. Once a schema is selected, it then controls the perception of the X-ray such that its features are interpreted and perceived as consistent with the schema. The expert then uses a set of procedures in conjunction with the selected schema to make a diagnosis. Therefore, the development of expertise in the case of X-ray diagnosticians in part consists of the development of interpretive schemas. Schema driven processing is in contrast to skilled pattern recognition in which the expert has learned to identify meaningful patterns or "chunks" of information. Although the recognition of basic patterns is a necessary component of expertise in X-ray diagnosis, it is not sufficient and does not explain individual differences in this skill.

Expertise in complex domains often requires the development of several different types of information processing skills. Relatively simple domains of expertise are less likely to tap numerous divergent cognitive and perceptual-motor abilities. For example, the primary determinant of expertise is motoric in the relatively simple skill of typing. Although cognitive constraints have some influence in producing variation in experts and novices, they are small compared to the perceptual-motor skills typing demands

(Gentner, 1988). Exceptional memory for restaurant orders is also a relatively simple domain of expertise. Exceptional memory for restaurant orders is largely based on the use of simple mnemonic techniques, which are cognitive strategies for recall (Ericsson & Polson, 1988). In contrast, complex domains such as physics, chess, and X-ray diagnosis most certainly draw upon a host of perceptual and cognitive skills. Performance variation in physics, for example, has been shown to be based on the extent of the knowledge base (Chi, Feltovich, & Glaser, 1981); however, the provision of adequate solutions to physics problems also demands procedural skill in mathematics and self-monitoring skills (Chi, Glaser, & Rees, 1982; Larkin, 1983; Simon & Simon, 1978). X-ray diagnosis may be schema driven, and therefore dependent on accurate schema selection (Lesgold, et al., 1988); however, experts must also possess accurate perceptual pattern recognition skills and an extensive knowledge base (Clancey, 1988; Lesgold, et al., 1988).

As is true of physics and X-ray diagnosis, Battle Command expertise is a highly complex domain. An Army commander must possess perceptual and cognitive skills that afford accurate interpretation of the battlefield situation. He must also be an effective leader and manager of human resources. He must have an enormous knowledge base concerning tactics, terrain, unit capabilities, enemy doctrine, weapons, etc. A commander must possess all of these skills and be able to quickly respond to dynamic conditions on the battlefield, often under considerable uncertainty. In short, Battle Command expertise involves the development of a host of perceptual, motor, social, and cognitive skills, all of which must interact in real time to effectively achieve the given mission. It is no wonder that it takes many years of study and training to achieve a level of expertise sufficient for effective Battle Command.

The complexity of Army Battle Command brings up an obvious question for any training research designed to facilitate the development of expertise. Which of the many skill elements of Battle Command expertise will be targeted in the training? Will the training be designed to facilitate leadership, management, planning, or any other of a host of skills that Battle Command demands? The present research is not concerned with improving tactics, leadership, or choice of course of action (COA), although each of these might be affected by the training developed for this project. Instead, this project concerns the development of expert situation assessment, which is an integral component of Battle Command as indicated by the Command Estimate. The core idea of this research is that experts assess the battlefield by using mental patterns that are matched in some way to real patterns present in battlefield situations. The general purpose of this work is to determine whether the development of expert situation assessment can be facilitated through training the particular cognitive and perceptual skill of pattern recognition in the domain of Army Battle Command.

Pattern Recognition. Pattern recognition is fundamental to human information processing and functioning because it constitutes the first interaction between the environment and the mind. In memory based models of human information processing, pattern recognition is the point where information in a sensory register is matched to information in long term memory (LTM) (Anderson, 1985; Howard, 1983; Klatzky, 1975). The information may be presented in any type of medium (tactile, auditory, visual, etc.), which is then compared to stored information. When a stimulus has been

analyzed, compared to the contents in memory, and a decision about its identity is made, it is said to be recognized (Klatzky, 1975). The central premise of pattern recognition is that when a pattern is recognized its *meaning* is derived through its *identification* and *classification*. Classification is necessary to recognition, forming the basis for identification. Note that labeling is not necessary to pattern recognition because we can recognize nameless patterns.

Traditional theories of pattern recognition focus on the nature of the stimulus being recognized and how it is stored in memory. These theories are *bottom-up* theories because they emphasize the stimulus driven nature of recognition. The two most common bottom-up theories posit LTM as storing (1) templates (Neisser, 1967) and (2) lists of pattern features to be matched to incoming stimulus information (Chase, 1986). The basic mechanism in both of these theories is that stimulus information is registered in sensory stores and then directly compared to stored memories, whether they be in the form of templates or feature lists. In template theories, classification of the stimulus is made by making a direct match to a stored template. In feature list theories, a stimulus is classified on the basis of its featural similarity to a stored category that is distinguished from other categories by its features.

Bottom-up theories have received substantial criticism and are currently untenable approaches to explaining pattern recognition. The criticism that has most often been levied against template models is that an incalculable number of patterns would have to be stored in LTM because real world stimuli are not identical. Humans are able to recognize patterns despite variations in size, orientation, and style. The research evidence indicates that stimulus patterns are matched to conceptually based categories of patterns rather than to miniature duplicate templates. Feature-list theories have been criticized, as have template theories, because they have difficulty explaining context effects on pattern recognition. For example, they have difficulty explaining findings that show that letters presented in the context of words are identified better than letters in isolation (Reicher, 1969). It is a mistake to ignore the influence of conceptual knowledge about patterns because there is evidence that this knowledge enhances our ability to recognize and categorize instances of different classes of stimuli (e.g., Rosch, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). In summary, information about categories of patterns appears to flow not only from the stimulus end (bottom-up) but also from the conceptual end (top-down).

To make template theory more attractive, variation can be introduced into the stored categories. At this point the literal template system starts to look more like a prototype system (Klatzky, 1975). Prototype theory has been presented as an alternative to template and feature-based theories in response to observed top-down, conceptual, and contextual effects on pattern recognition. Recognition based on prototypes is not the same as template matching, which requires an exact match. Prototype recognition is based on a comparison of incoming stimulus information with stored prototypes representing the average of all members of the category. Prototypes are said to develop through an abstraction process in which we extract a central tendency for all of the patterns that belong to a particular category. Once a prototype is established and stored in memory, it can then be used in pattern recognition. If the stimulus information bears

a family resemblance to the prototype, and the resemblance meets or exceeds a threshold value, it is recognized as a category member. If the resemblance falls below some threshold value on the index, we conclude that it is not a member. Since the prototype is an average of all members of the category, a specific pattern can vary from the prototype to some extent and still retain its category membership.

Perhaps the most accepted theoretical account of pattern recognition is an interactive model in which a pattern is recognized as the result of both bottom-up and top-down processing. Rumelhart's and McClelland's (1981) model of word recognition, which has received further development in the form of parallel distributed processing (PDP) theories of memory (McClelland & Elman, 1986; McClelland & Rumelhart, 1986), is one of the first interactive models. In interactive and PDP models, information is assumed to flow up from the early visual processing stages to pattern detectors. In Rumelhart's and McClelland's model, visual information "excites" letter and word detectors. Top-down processing is included in that word detectors send excitation back to the letter detectors to enhance the excitation of letters in words.

The validity of bottom-up or interactive models of pattern recognition are largely irrelevant to issues concerning the potential benefit of pattern recognition training. However, the evidence that indicates pattern recognition is influenced by conceptual knowledge and prototypes has important implications for a pattern recognition training course. Merely presenting a large number of patterns to students would not be sufficient for developing these skills. The meaning of each pattern should be clearly presented and prototype patterns should be carefully formed. In the case of Army tactical training, students should be taught first to recognize different prototypical battlefield patterns because they would provide the building blocks needed for recognizing other battlefield patterns. Care should be taken to ensure that the critical attributes of each prototype are identified during training development and that prototypes are maximally distant from one another.

In the next section we continue our discussion of instructional issues pertinent to the development of pattern recognition training.

<u>Training Pattern Recognition</u>. As a theoretical construct, pattern recognition training is a novel concept. Very few formal treatments of pattern recognition training can be found in the literature and very few empirical investigations have been devoted to its development as a pedagogic tool, or to identifying the potential benefits of this form of instruction. It is clear that every day people as well as experts have extensive pattern recognition abilities. It is not clear, however, how they obtain these skills. Do they receive instruction in most cases, and if so, how are they typically taught? Is there a best way to teach such skills? What distinguishes pattern recognition training from other types of training and education?

It is curious that so little formal research has been devoted to pattern recognition training because, as we previously discussed, skilled recognition is consistently found to be one element of expertise. The development of skilled pattern recognition is also one of the few cases in which the normal duration of the development of expertise has been significantly shortened. By and large, the development of expertise appears to

involve the acquisition of complex cognitive structures and skills that requires many years of structured practice and focused learning. However, Biederman and Shiffrar (1987) were able to increase the performance of one set of novices to a level equivalent or better than a group of experts with a simple one-page set of instructions that identified the critical elements of patterns to be classified. Specifically, they developed pattern recognition instruction as the basis for developing expertise in chicken sexing.

Performance levels of chicken sexers are impressive and typically take years to acquire. Professional sexers are highly accurate (about 98% correct classifications) and can classify 1,000 chicks per hour. In the 1930s, several training schools were founded in California to meet the industry's needs because this skill was not easily found in the general populace. Professionals report that it takes approximately 10 years to reach high accuracy levels, mainly due to the infrequent exposure to anomalous cases.

In their research, Biederman and Shiffrar (1987) first analyzed the recognition skills of expert chicken sexers. Their expert systems analysis identified a simple contour difference between male and female chick genitalia. In males, the critical region is convex; in females, the head is flat or concave. To determine if the skill could be easily developed in novices, the researchers developed a single sheet of training instructions that described the critical features distinguishing male and female chicks and provided prototypical diagrams of male and female genitalia. Their experimental procedure was conducted as follows. First, they presented 18 pictures of chicken genitalia to a group of 36 novice sexers and asked them to indicate the sex of the chicks. They then presented half of the individuals from the novice group with the instructions they developed and asked them to reclassify the 18 pictures. Five professional sexers were also asked to classify the pictures. As a result of the training, the novices performed as well or better than the professionals. The novices scored an average of 60.5% correct prior to reading the instructions and 84% correct after instruction. The novice group who did not receive instructions scored only 54.1% correct on the second testing. The professionals averaged 72% correct choices. These researchers attribute the success of the training to the specification of perceptually invariant qualities of the stimulus:

> When one is faced with the task of distinguishing among highly similar exemplars in difficult subordinate-level classification tasks, one typically achieves high levels of accuracy, not by creating precise templates, but by discovering (or asking) where to look and what viewpoint-invariant contrast to seek (Biederman & Shiffrar, 1987, pg 1181).

Despite a lack of formal treatment, studies such as Biederman's and Shiffrar's often employ instructional methods that might be defined as pattern recognition training. In most cases, the stated purpose of the study has been to investigate issues other than the development or effectiveness of pattern recognition training. For example, human subjects have been trained to recognize patterns to determine how people acquire categorical knowledge (e.g., Knowlton & Squire, 1993), to identify the stimulus variables that affect recognition (Boltz, Marshburn, Jones, & Johnson, 1985; Charness & Bregman, 1973; Murray & Szymczyk, 1978), and to determine the effectiveness of multi-faceted cognitive training in applied situations (Smith, Waters, & Edwards, 1975). Comparative psychological studies have trained pigeons and other animals to recognize patterns to investigate their discrimination learning ability (e.g., Lombardi & Delius,

1988; Neuenschwander, 1984) and the pattern recognition ability of computer instantiated connectionist (neural network) models has also been investigated (e.g., Carpenter, Grossberg, & Reynolds, 1991; Daniel & Fernando, 1991; Katz, Gately, & Collins, 1990; Stevens & Latimer, 1992). The theoretical and empirical issues of concern in these studies, however, are only loosely related to the development and evaluation of pattern recognition training as a pedagogic tool.

A few researchers have suggested that teaching pattern recognition is important to problem solving ability (Frederiksen, 1984; Gregg, 1974; Salomon, 1974; Simon, 1980). Simon, for example, notes the need for improving students' recognition skills because professional skill is partly dependent on one's ability to rapidly identify cues that signal actions. Although the particular pedagogical methods of pattern recognition training have not been investigated, most researchers seem to think that the primary method is extensive practice with feedback (e.g., Frederiksen, 1984; Gregg, 1974). Another possibility is teaching pattern recognition skills through modeling of appropriate observation. For example, one study successfully used a zooming technique with film to focus on picture details (Salomon, 1974).

It is easy to think of examples in which patterns are trained. For example, we learn to read by first learning the visual and auditory patterns of the alphabet. Once we are skilled recognizers of letters, we learn to recognize words. We may begin by sounding out the letters of each word phonetically, but in short time we learn to recognize the pattern of letters as a particular word with particular meaning. Learning the shapes of countries and states, the identity and meaning of musical notation, architectural styles (e.g., Tudor, Romanesque, Spanish), and the identify of common objects (e.g., animals, cars, etc.) are all examples of patterns we have learned in one way or another. Bird watchers often develop identification skills through the use of field guides, the most useful of which are organized by the identifying features of avian species. In fact, we learn to recognize many different patterns in many different domains, whether or not formal instruction is given. The reader may remember learning the shapes of states and countries of the world through flashcards, for example. Certainly, our first experiences in school involve formal instruction in the alphabet and learning to read. Other patterns (e.g., animals and objects) we pick up through simple experience (such as learning to recognize faces) and informal instruction from our parents and teachers. The common means by which these patterns are learned in everyday life is probably through repeated exposure, some guidance, and feedback.

Given the limited research on pattern recognition as a pedagogical tool, what guidance can be derived for developing a pattern recognition training course? We know from the research on expert/novice differences that patterns are domain specific and have meaning only in the context of the domain. Perceptual skills are acquired to meet specific demands of encoding and accessibility in specific activities in a given domain (Ericsson, & Charness, 1994). We also know that high levels of recognition skill are bound by the *meaning* of the patterns. Therefore, a pattern recognition course should not only teach the perceptual aspects of the domain specific patterns, but also their meaning. We also know that current accounts of pattern recognition favor

interactive models and the use of stored prototypes as a representational basis (e.g., Knowlton & Squire, 1993; Rosch, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Pattern recognition training, then, should focus on the development of prototypes. In summary, current knowledge about pattern recognition information processing suggests that a pattern recognition course include (1) extensive practice with feedback and information about (2) the meaning of patterns, (3) the perceptual aspects of patterns, and (4) prototypical patterns.

The novelty of the formal concept of pattern recognition training requires its definition. Generally speaking, we propose that the goal of a pattern recognition course is to develop a mental catalog of patterns that are used to identify, interpret, evaluate, and derive meaning from perceptual stimuli in a particular domain of expertise. Training must first develop the ability to distinguish categories or classes of patterns. Second, it must produce skilled recognition such that students learn to identify patterns in a quick and accurate manner. And third, knowledge about the meaning of the patterns in the context of the domain must be delivered to the student. We therefore define pattern recognition training to be any instructional program designed to engender (1) knowledge about the *critical features* of patterns that distinguish them from other patterns, (2) *skill* in recognizing patterns, and (3) knowledge about the *meaning* of the patterns. Each of these three elements of a pattern recognition course must be limited to a particular domain of expertise such as chess, physics, or Army Battle Command. One might think of these three elements as addressing both the bottom-up and top-down aspects of pattern recognition. Learning the critical distinguishing features of pattern categories constitutes the perceptual aspect and learning the pattern categories' meanings and relations constitutes the conceptual, cognitive aspect of pattern recognition. Developing skill in pattern recognition is the interaction of these two components.

Purpose of this Research

The general purpose of this research was to evaluate the effectiveness of pattern recognition training on Battle Command performance. The general hypothesis that direct training in pattern recognition could circumvent and greatly shorten the time necessary to assimilate battlefield patterns was examined. The central idea was that skilled performance that normally takes several years to develop, might be taught in 8 to 40 hours of direct pattern recognition training. Students might benefit from pattern recognition training in a number of ways: (1) the amount of information learned about battlefield features may be greater with a pattern recognition course than with traditional Army training methods, (2) the amount of pattern information retained may be greater with a pattern recognition course, (3) pattern recognition may produce better performance in recognizing novel battlefield patterns, and (4) students with different cognitive styles might differ in their ability to learn from a battlefield pattern recognition course. Each of these hypotheses are developed in greater detail below.

Hypotheses

The first hypothesis of interest in this research was that "the amount of information learned about battlefield features may be greater with a pattern recognition course

than with traditional Army training methods." This hypothesis arises from research in problem solving and expert/novice differences, which has indicated that superior pattern recognition skills are often a marker of outstanding performance. The idea that pattern recognition training might facilitate the development of expertise is particularly compelling for the domain of Army Battle Command because highly experienced commanders are known for their quick and accurate assessment of battlefield situations, leading one to hypothesize that their situation assessment skills are driven by pattern recognition. It is no accident that one of the few studies that has addressed the utility of pattern recognition as a training tool investigated the relation between pattern identification skill and situation assessment in a simulated battlefield environment (Kass, Herschler, & Companion, 1991). The authors found that subjects who were trained to recognize patterns through the use of only task-relevant cues performed better in a realistic battlefield test condition that those who did not receive such training. They argue that pattern recognition skills are largely responsible for individual differences in situation assessment. If this is true, then individuals trained in battlefield pattern recognition should have more critical domain knowledge than those trained by current Army methods.

A second hypothesis suggests that not only will individuals trained with pattern recognition methods obtain more pattern knowledge, but they will also retain their knowledge better than those trained by standard methods. As suggested by Gardner (1983), once patterns are learned, they are almost impossible to forget. Therefore, retention of information concerning patterns should be much better for individuals who receive pattern recognition training.

There is also reason to believe that individuals trained with pattern recognition methods may be able to better interpret novel battlefield patterns than individuals trained by other methods. Pattern recognition training that incorporates prototypes and presents many different instances of patterns that fall into a single category would facilitate flexibility in identifying patterns. One would expect that students would be generally willing to accept anomalous or novel battlefield patterns as members of a category. In contrast, methods that emphasize rule-based classical definitions of patterns and fail to provide extensive practice in identifying variations of patterns would tend to elicit limited pattern recognition skills. A third purpose of this research was to examine the possibility that pattern recognition training improves perception of novel battlefield patterns.

Anecdotal and empirical evidence suggests that some Army officers seem to have an ability to glance at a battlefield situation portrayed on a map and form an immediate and accurate picture of the situation. Others with identical training seem to lack this skill; they cannot develop situation awareness until the situation is described in words and numbers. There is no doubt that individual differences play an important role in how officers obtain their skills and knowledge and how well they perform. One type of training may be better for one group of officers while another method might be better for another group.

Individuals vary on a very large number of personality and intellectual traits and abilities. Two traits or abilities that might bear specific influence on the development of

pattern recognition skills are field dependency and spatial ability. Field dependency (or independency) refers to an individual's preferred mode of processing information. The term field dependence was coined during Witkin's early research that used a rod portrayed inside a frame to assess cognitive style (Witkin, Moore,Goodenough and Cox, 1977). The rod was tilted at various degrees from upright, and the subject was asked to estimate the degree of tilt. Independently of the rod, the surrounding frame (called the field) was also tilted at various degrees. When the frame was tilted, some subjects had difficulty in estimating the tilt of the rod; it was as if they perceived "upright" as "toward the top of the frame," so that with a tilted frame, a rod with exactly the same tilt was said to be upright. These subjects were called "field dependent" because their judgments depended on the tilt of the field. The "field independent" subjects had no problem in estimating the tilt of the rod, no matter what orientation the frame was set. Later research showed high correlations of the rod-and-frame test with another test, the Embedded Figures Test, in which field-dependent subjects have difficulty finding a simple figure embedded in a more complex figure (Witkin, et al, 1977). Today, it is the Embedded Figures and Hidden Figures Tests (Ekstrom, French and Herman, 1976) that are typically used to assess field dependence/independence. Sometimes these tests are said to measure global versus analytic style (dependence versus independence). Individuals who are field independent may find pattern recognition training difficult because it promotes rapid decisions on the basis of a holistic assessment, rather than an analytic evaluation of the situation. A fourth hypothesis that this research addresses is whether there is a relationship between an individual's cognitive style (field dependency or independency) and his or her ability to profit from pattern recognition training. Subjects were classified on cognitive style using the Hidden Figures Test (Ekstrom, et al., 1976).

We also asked whether spatial ability mediates learning from a pattern recognition course. People high in spatial ability are likely to understand maps; they are more likely to be able to interpret map symbols because they are better able to take the perspective required for such interpretation. For example, one test of spatial visualization was used to predict pilot success in World War II. Pilots who were high in spatial visualization were almost always rated in the highest categories of proficiency. It is important to note that while the benefits afforded by pattern-recognition training may be greatest for students of high spatial ability, these benefits will not necessarily be restricted to such students. For students with low spatial ability, pattern recognition training may provide the means for extensive practice in classifying battlefield patterns. Subjects were classified on spatial ability using the Paper Folding Test (Ekstron, French and Herman, 1976).

Training Development

A first step in developing pattern recognition training for any domain is to identify the patterns that are meaningful, important, and utilized by experts in the area. Any domain will encompass numerous patterns that are learned as one becomes proficient in the field. Some of the patterns may be learned almost immediately by the novice, while others may take many years to recognize and understand. Knowledge of some patterns may be a marker of expertise while knowledge of other patterns in a domain may be only the first step in the development of highly skilled performance. For example, the novice chess player quickly learns the acceptable patterns of movement for each chess piece, although this knowledge does not make one a chess master. Experts in chess can be distinguished from novices in their knowledge of larger meaningful patterns of chess board situations, which take many years to appreciate. If one wants to develop expertise through a pattern recognition course, then, it is important to identify those patterns that are critical to expert performance.

Identifying the pattern knowledge that distinguishes expertise is more complex than it may at first seem because the pattern knowledge that *most* distinguishes experts from novices is likely to be the *least* obvious to anyone but an expert in the domain. If all the patterns in the domain were apparent to any individual, experienced or otherwise, pattern recognition would not be a hallmark of expertise. Moreover, it is often exceedingly difficult to elicit such knowledge from experts because they may be unaware they possess or use such information, or they may have difficulty verbalizing their knowledge. Experts often believe that everyone "views" their domain in the same way; hence, they often fail to see the need for describing their knowledge.

Battlefield patterns relevant to Army Battle Command are particularly esoteric because the domain is highly complex and the concept has received little research attention. Very little is known about expert pattern knowledge of battlefield situations. One may hypothesize that battlefield situations contain numerous patterns (e.g., enemy patterns of movement, deployment, weapon systems, and terrain patterns) and that Battle Command expertise includes skilled pattern recognition. However, research has not yet substantiated this claim, and Army doctrine makes no mention of the need for expertise in pattern recognition. Moreover, if there are battlefield patterns that are important to Battle Command, they are not documented.

Hence, the first task in developing pattern recognition training relevant to Battle Command was of considerable magnitude and importance: to determine which of the large number of possible battlefield patterns should be taught. It was also important to investigate the role of terrain pattern recognition in the context of Battle Command because it may or may not be a marker of expertise in this particular domain. Therefore, it was necessary to address the question of its importance to expertise in Battle Command. The main goal of this first step was to answer the following question. If evidence could be obtained that pattern recognition was significant to Battle Command, then knowledge of which of the many battlefield patterns distinguishes highly experienced Army officers from novices?

Identifying Militarily Significant Patterns

To address the questions noted above, a series of knowledge elicitation (KE) sessions were conducted with several different groups of experienced Army officers. We began by conducting interviews with officers at Fort Drum, New York. The purpose of this first knowledge elicitation session was to determine the type of information, in the form of patterns, that was available to tactical planners at each point in the mission planning process. We sought to identify the form that information typically takes and the critical features that define the information.

First Knowledge Elicitation Session

Method. Seven officers were individually interviewed at Fort Drum; each interview was approximately four hours long. The qualifications and characteristics of the Subject Matter Experts (SMEs) are listed in Table 1. All except one had experience as a Battalion (Bn) or Brigade (Bde) operations officer (S3) two had Division level operations officer experience (G3), and most had other experience of value as well: two with expertise in Field Artillery planning, one with personnel (S1) and logistics (S4) officer experience, and one with civil affairs (G5) experience.

Table 1.
Qualifications of Subject Matter Experts
in First Knowledge Elicitation Session

Rank	Bn/Bde Battle Command	Training	Other
Major	S3, Executive Officer	Tactical Commanders Development Course	--
Major	S3 (Bn + Bde)	Command and General Staff College (CGSC)	Division G3
Major	S3	Command and General Staff College	--
Lt. Colonel	S3	Command and General Staff College	Division G3
Lt. Colonel	S3	Command and General Staff College	G5 operations
Major	S3	Command and General Staff College (correspondence)	S1, S4
Captain	--	Command and General Staff College (correspondence)	Company Commander

The knowledge-acquisition technique used was Information Needs Analysis (INA) (Geiwitz, Kornell, & McCloskey, 1990). INA is a form of Task Analysis in which, instead of the required knowledge and skills to perform each task step, the information needs for each task step are determined. In the course of INA, prepared graphics were used for comment and comparison and the SMEs drew some of the graphics they

described on paper. INA was used for this project to elicit the battlefield patterns that are used by the SMEs to make mission-planning decisions. An assumption made in this analysis was that important battlefield patterns must be part of the stimulus material available to commanders and planners in the context of the mission-planning process. We reasoned that if the patterns were militarily significant, they would have to be present in some form on some stimulus material to which a commander would have access. The focus of the interviews and the INA was on the entire battlefield situation so as not to prematurely limit the investigation to one or two components of the battlefield. We assumed that if pattern recognition were important to Battle Command, the critical patterns would be contained in the battlefield situation.

Results. The results presented here are organized in terms of three main findings with relevant data collected from all the SMEs on each of the three topics. The foremost topic was the battlefield patterns the operations officer uses in mission planning. As we noted above, we assumed that significant patterns of the battlefield situation would be part of the stimulus materials presented to the commander and his staff in the mission planning process. Hence, we focused on the types of documents and materials used in mission planning.

Finding #1. **Battlefield patterns are represented in particular stimulus materials available to commanders and planners in the context of the mission-planning process.** The SMEs at Fort Drum were trained in the Command Estimate (ST 100-9), which outlines the mission-planning process for the Corps and Division level but which is suitable also for Brigade and Battalion planning. Below we briefly describe the process and associated stimulus material that describes the battlefield situation to the commander and his staff.

The planning process begins with the receipt of the mission from higher headquarters, usually in the form of an Operations Order (OPORDER), but sometimes in the form of an Operations Plan (OPLAN), Alert (WARNING) Order, or a Fragmentary Order (FRAGO). The first step in the planning process is Mission Analysis, which has two primary products: the Commander's Restated Mission and a Warning Order to subordinate commands. The Warning Order allows the lower commands to begin their planning process, as well as prepare for the mission. On the basis of the Restated Mission and the information available, the commander issues his guidance. The planners then develop the possible courses of action (COAs), three if time permits. However, decisions are sometimes modified later in the mission-planning process as intelligence information, including spot reports and status reports, is still coming into the Plan Cell. After the three COAs are constructed, they are analyzed by war-gaming and compared to recommend the best of the three to the commander. Planners usually prepare a decision matrix, showing each of the three COAs with rows describing important features for the mission.

The stimulus materials used by the commander and his staff in the mission planning process describe the battlefield situation. Of utmost importance is the OPORDER (or in other forms, an OPLAN, WARNING, or FRAGO). The OPORDER contains critical information about the enemy situation and the friendly situation. As

we will see below, other materials include maps and overlays developed in the Intelligent Preparation of the Battlefield (IPB) process as well as additional verbal information obtained through intelligence efforts.

<u>Finding #2.</u> **Battlefield patterns may not only be represented in graphic and visual stimuli; they may also be represented in text or verbal information, which may set the context for the perception of graphics.** We return our focus to the tactical stimuli available to the planners before they begin to construct their COAs. Much of this material is graphic, usually maplike, often in the form of overlays that fit over maps representing the area of interest. However, much of the information is presented in text. For example, the OPORDER contains words, sentences, tables of data, task organization lists, etc. This textual information often sets the context for the perception of tactical graphics. The OPORDER forms the context for the perception and interpretation of facts, data and assumptions about the enemy situation, the friendly capabilities, and the terrain and weather of the battlefield.

The SMEs identified five textual inputs as primary settings of the tactical context: the warning order, mission, restated mission, commander's intent (2 levels up), and the commander's initial input. The last three of the five textual inputs contain several other products that further describe the situation. The restated mission is based on the staff's listing of specific and implied tasks, plus assembled facts and assumptions relevant to the mission. Facts include personnel status reports, the responsibility of the S1, terrain and weather facts are reported by the S2 along with known enemy information; the S3 is responsible for holding to the facts of the originally stated mission, the commander's intent, current task organizations, friendly unit capabilities, and time available; the S4 gathers the logistical facts. Assumptions are developed to replace necessary but missing facts.

<u>Finding #3</u>. **The battlefield situation is composed of a combination of three primary categories of information: enemy situation, friendly situation, and the terrain in the area of operations.** Both the Command Estimate textbooks and the SMEs at Fort Drum emphasize these three basic sources of information. This information is interpreted in the context of the restated mission and the commander's intent.

Important elements of the enemy situation include the size of the unit, strength of the unit, probable enemy intentions, current location, enemy intelligence capabilities, enemy logistics, civil affairs issues, and personalities. This information is combined with terrain analysis to obtain information on the probable layout of enemy troops, potential and probable avenues of approach, probable enemy actions, critical areas in the event template, timelines, critical events decision points, target areas of interest, and high value targets. Important elements of the friendly situation are task organization, friendly strength, equipment capabilities, support, and unit status.

<u>Second Knowledge Elicitation Session</u>

Armed with the information and findings obtained from the Fort Drum interviews, the possibility that the entire battlefield situation could constitute a pattern was investigated. It is important to remember that pattern recognition is essentially a

classification task, and that the outcome of the process is the identification of a stimulus. Therefore, we sought to determine if battlefield situations could be effectively classified and identified.

__Method.__ Sorting was chosen as the knowledge elicitation technique to be used in the second session. Sorting is essentially a classification exercise in which an individual groups stimulus materials into categories; hence, the products of sorting constitute external evidence of classification and identification. Three retired Army officers were interviewed in the second round of knowledge elicitation sessions. Prior to retirement, one had recently been an instructor at Fort Leavenworth's Tactical Commanders Development Course and had extensive experience. A second SME was an Army aviator and the Chief of the Flight Simulator Division at the U.S. Army Aviation Center, Ft. Rucker Alabama. The third evaluator had twenty years of military operational experience that included command assignments. The three SMEs' qualifications and experience are summarized in Table 2.

Table 2.
Qualifications of Subject Matter Experts
in Second Knowledge Elicitation Session

Rank	SME #	Bn/Bde Battle Command	Training	Other
Lt. Colonel	1	Division G3 officer, Executive Officer of a Field Artillery Battalion	Command and General Staff College, School of Advanced Military Studies	Developer and Instructor of Tactical Commanders Development Course, Military Science Instructor
Lt. Colonel	2	S3, Aviation Company Commander	Command and General Staff College	Deputy Director for Department of Tactics at Command and General Staff College
Lt. Colonel	3	G3 Advisor, Bde Operations Officer, Company Commander	Command and General Staff College	Associate Professor of Military Science at University of California

OPORDERS were used as one set of stimulus materials to be sorted because they offer a clear and detailed description of a military situation, they are always received by a commander and may be the only information he receives, and they are highly familiar to Army personnel. Each interviewee was presented with a set of OPORDERS that described a variety of situations and asked to sort the materials into meaningful categories. A second set of stimulus materials to be sorted were a set of 78 battlefield elements. The elements included, for example, the friendly mission, artillery, task organization, enemy objectives, key terrain and enemy training level. These elements were obtained from the results of the first knowledge elicitation session and our study of various Army field manuals. We reasoned that if the elements could be classified, the categories that they formed might constitute patterns within the battlefield situation.

Results. The SMEs had difficulty classifying the OPORDERS because they regarded each as a unique situation. The tendency was to create nearly as many categories as there were OPORDERS. Nevertheless, a few high level categories were identified including situations that were offensive vs. defensive, situations at different unit levels such as brigade vs. battalion, type of terrain in which the battle was placed, and variations on task forces. In summary, entire battlefield situations, which contain a tremendous amount of information about the enemy situation, friendly situation, and terrain, are not particularly amenable to classification. In a strict definitional sense, then, we would not regard them as patterns. If pattern recognition is an important component of Battle Command expertise, it apparently does not employ entire battlefield situations, as represented by OPORDERS, as categories.

On the other hand, the 78 battlefield elements were readily classified. Figure 1 depicts one SME's (#2) spatial sort of the elements, which is representative of all three SMEs' sorts. As can be seen in Figure 1, the battlefield situation can be represented as eight categories of elements: the battlefield situation, mission analysis, type of operation, enemy intentions, the IPB process, enemy capabilities, resources, and the allocation of resources. The arrows depict associations and the spatial layout depicts the degree of association between the categories, as indicated by the SME.

Third Knowledge Elicitation Session

Two conclusions were derived from the results of the second session. First, entire battlefield situations are difficult to classify; therefore, they probably do not constitute patterns in a strict sense. In contrast, elements of the battlefield are readily classified into higher level categories, many of which probably contain important patterns that experienced Army officers learn to recognize and use in mission planning. For example, "types of operations" is a higher level category that contains a number of identifiable patterns such as a river crossing, a penetration of friendly lines, and a pursuit. Similarly, the IPB process includes patterns such as cover and concealment, avenues of approach, and terrain. The results of the second session were fruitful in that they identified a host of potential patterns that are important to the mission planning process and are likely to be ones that are related to the development of expertise.

The development of a pattern recognition course that encompassed all possible patterns identified in the second session would be an enormous undertaking and was beyond the scope of this project. To limit the pattern recognition training to a manageable set of patterns, one category of patterns was chosen from those identified in the second session. For several reasons, we selected various elements of the IPB process that were associated with terrain. Not in order of importance, the first reason for the selection of terrain patterns was that the stimulus materials that represent terrain are presented visually in the form of maps, facilitating development of training materials. Second, terrain patterns themselves are spatial in nature, which makes them compelling patterns. Although enemy auditory transmissions may also be considered classifiable patterns, they are less compelling patterns because they lack a spatial-visual component. Third, anecdotal reports of commanders' expertise often describe the ability to

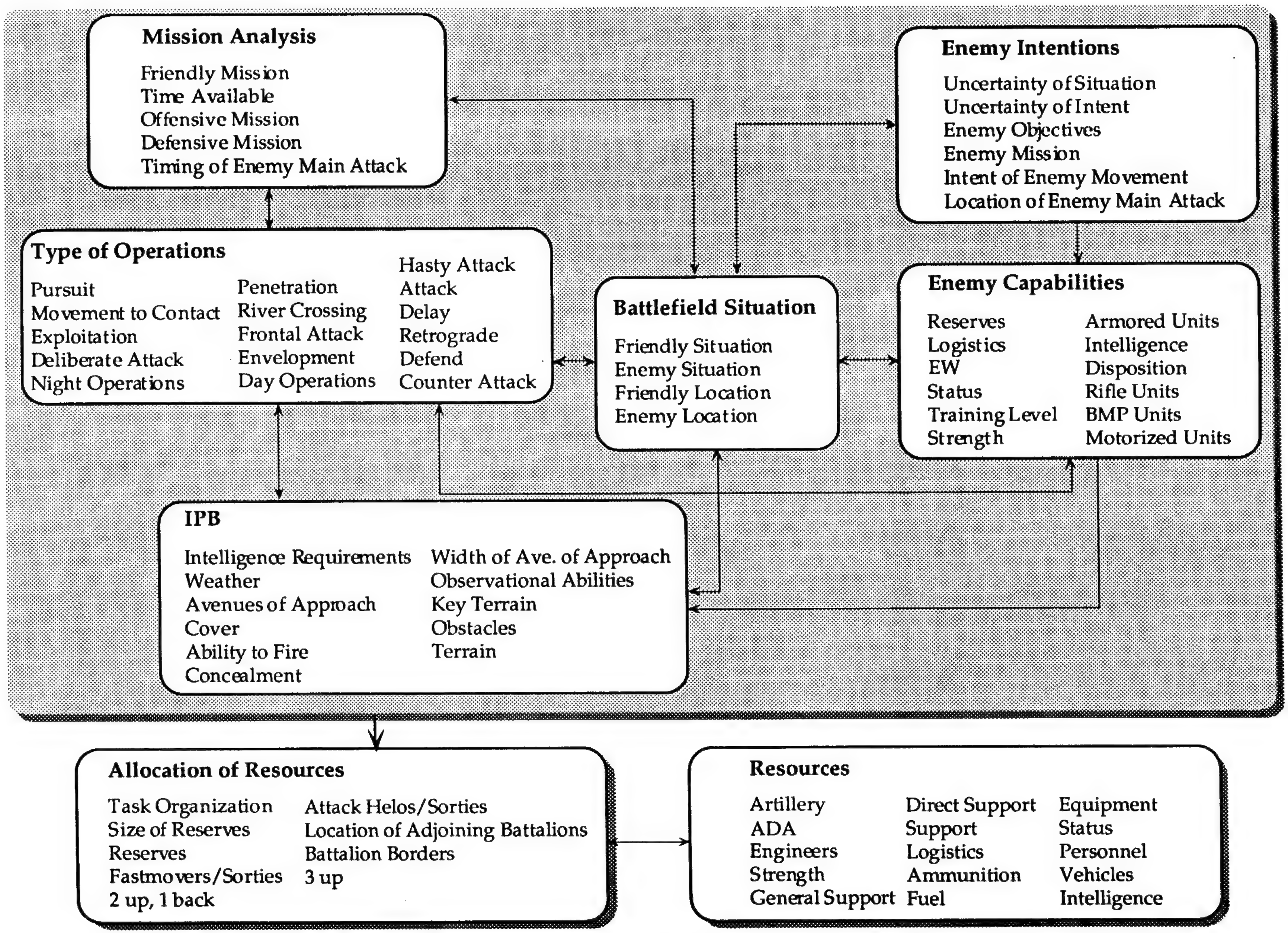

Figure 1. Example sort of 78 battlefield elements.

immediately assess a situation upon looking at the map of operations. In other words, terrain is a critical determining factor of the battlefield, and knowledge of terrain and its military significance is central to Battle Command expertise. Finally, terrain analysis is taught in all levels of Army training, in college Reserve Officer Training Corps (ROTC) to Officer Basic and Advanced Courses, making possible the comparison of a pattern recognition course and traditional Army training methods. The third knowledge elicitation session focused on the further development of terrain patterns.

Method. Two SMEs (#1 and #2) who participated in the sorting exercises of the second session, served as SMEs in this last session. As can be seen in Table 2, both had extensive experience teaching mission planning, which included the importance of terrain considerations and their military significance.

Two techniques were used in this session. First, the SMEs were simply interviewed and explicitly asked to identify all of the militarily significant terrain patterns they could. A second technique was necessary to identify patterns that the SMEs might have failed to include because they (1) did not remember them, (2) were not aware he used them, or (3) could not verbalize their knowledge. A protocol analysis was used to extract information that was not obtained from the interview. Each SME was asked to analyze the terrain of several battalion level sectors, thinking aloud as he progressed in his analysis.

Results. The third knowledge elicitation session produced a list of tactical terrain patterns, which was to form the basis of the pattern recognition training. The patterns that were elicited through explicit instruction were hill slopes, ridges, spurs, cliffs, depressions, draws, wadis, saddles, valleys, roads, railroads, bridges, overpasses, built-up/urban areas, flat terrain, swamps, rivers, lakes, forested areas, kill sacks, hills in depth, mountain ranges, and mountain passes. Through observation of the SMEs' analysis of the sectors, several other patterns were elicited. These included canalizing terrain, road networks, disadvantageous (exposed, maneuver restricted, impeded) terrain adjacent to high ground, mobility corridors, ground avenues of approach and air avenues of approach. Greater detail on the river and forested area patterns were also obtained through the protocol analysis. Specifically, rivers bear different significance depending on whether they must be crossed or not. If they must be crossed, the path that the river follows with regard to the enemy's advance is important. If the river bulges in the opposite direction to the enemy advance, the enemy has the advantage at the river crossing. If the river bulges in the same direction as the enemy advance, the defender has the advantage. Forested areas were further differentiated by coniferous vs. deciduous, vs. mixed, vs. trees and brush.

Developing a Catalog of Patterns

Once the basic patterns had been identified, the next step in the development of the pattern recognition training was to select those patterns that were particularly significant to mission planning. Although topographic maps are replete with identifiable patterns that represent a wide variety of terrain features, not all such patterns are

militarily significant. To ensure that the pattern recognition training course was applicable to military concern and study, only those patterns that possessed a high degree of military significance were included in the student text. For the purposes of this project, military significance was judged on two criteria. For inclusion in the training, a specific terrain pattern had to be either (1) currently described in the Army's Map Reading and Land Navigation Field Manual (FM 21-26), or (2) identified by at least one military SME and confirmed by at least one other SME. These criteria eliminated air avenues of approach as an acceptable pattern.

Identifying Variance in Patterns

The next step in the development process was to identify acceptable variance within pattern categories such that the members of the category shared critical features but varied in their non-critical components. For example, not all uniform hill slopes look the same. The contour lines are sometimes placed very close together and sometimes far apart, depending in part on the contour interval and in part on the slope itself. However, they all share one critical feature: the contour lines are evenly spaced along the slope. To determine acceptable variance one of the SMEs was instructed to look for varying and odd instances of pattern categories. This information was used to identify not only the range of membership in the categories, but also the defining or invariant features of each category.

Designing the Pattern Recognition Training

The final step in the development of the training was to design the course itself. Based on a review of the relevant training literature regarding pattern recognition the design of the training incorporated four elements: (1) extensive practice with feedback and information about (2) the meaning of patterns, (3) the perceptual aspects of patterns, and (4) prototypical patterns. The course materials were developed following these guidelines, resulting in three books, (1) a Student Text, (2) a workbook that contained exercises, and (3) a response booklet in which students wrote their answers to the exercises. Each of these are described in greater detail below.

Student Text. The purpose of the student text was to define each of 40 terrain patterns and to deliver important information regarding the patterns' significance with regard to military goals and purposes. To ensure that the training could be conducted within a reasonable time span, the course was limited to a particular military context in which the patterns might be used. First, only those terrain features that possess military significance to a battalion level unit command were included in the training, although many would certainly be of concern to commanders at other echelons (e.g., company, brigade, and possibly division). Second, only those patterns relevant to a defensive mission were included, which is not to say that the patterns would be irrelevant to other missions. Third, each pattern was relevant to a friendly mechanized or armored unit facing an enemy mechanized or armored unit.

The text contained definitions and discussions of two different types of tactical patterns: single-feature and multiple-feature.[1] Single-feature patterns, of which 30 were described in the student text, consisted of a single terrain feature such as a valley or ridge. Multiple-feature patterns were defined as several single-feature terrain features that form a composite tactical pattern when combined with a known enemy direction of movement. The student text described 10 multiple-feature patterns. An example of a multiple-feature pattern is a bowl formed by several hills or other high ground in a semicircular spatial relationship to one another that may be used as a "kill sack".

The single-feature patterns described in the text are organized into five groups corresponding to high ground, low ground, vegetation, movement areas, and bodies of water. Figure 2 shows the single- and multiple-feature patterns as well as their organization in the text.

Each pattern in the text was described and defined in a standard format that included the pattern name, pattern subtypes, a general definition, a schematic, the pattern's critical features, its military significance, and any associated military advantages and disadvantages. Figure 3 provides an example of a pattern description of saddles taken from the student text. For each pattern, the direction of enemy movement was described in parentheses following the *pattern name.* The *schematic* for each pattern graphically depicted the critical features that distinguish the pattern from other patterns. The schematic can be considered the "ideal" graphic or prototype pattern that might be found on a map. Of course, maps very rarely contain "ideal" patterns. In some cases, the direction of enemy movement was also indicated in the schematic by an arrow. The *critical feature* section of the pattern description gave a verbal description of the critical features that distinguish one pattern from the rest. The *military significance* of each pattern was described and this information was summarized in the *advantages* and *disadvantages* sections of each pattern description. Also included in the student text was introductory and instructional information provided to direct the students' study of the material.

Workbook. The purpose of the workbook was to provide the student with practice in recognizing the terrain features described in the student text. The student text instructed the student in the critical features and military significance of the patterns while the exercises in the workbook provided a format in which the student could practice identifying terrain features and receive feedback to hone his or her recognition skills. The workbook contained two different types of exercises each with a different training objective. The first type of exercise, herein called "identification exercise," required students to identify marked terrain features on 1:50,000 scale copies of military topographic maps. The training objective of this set of exercises was to teach

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[1] Although the patterns described in the training are common to military doctrine, the distinction between single- and multiple-feature patterns is not typically acknowledged in the Army. The differentiation between these two types of patterns was included within the pattern recognition training course primarily for organizational purposes and ease of presentation of the content material.

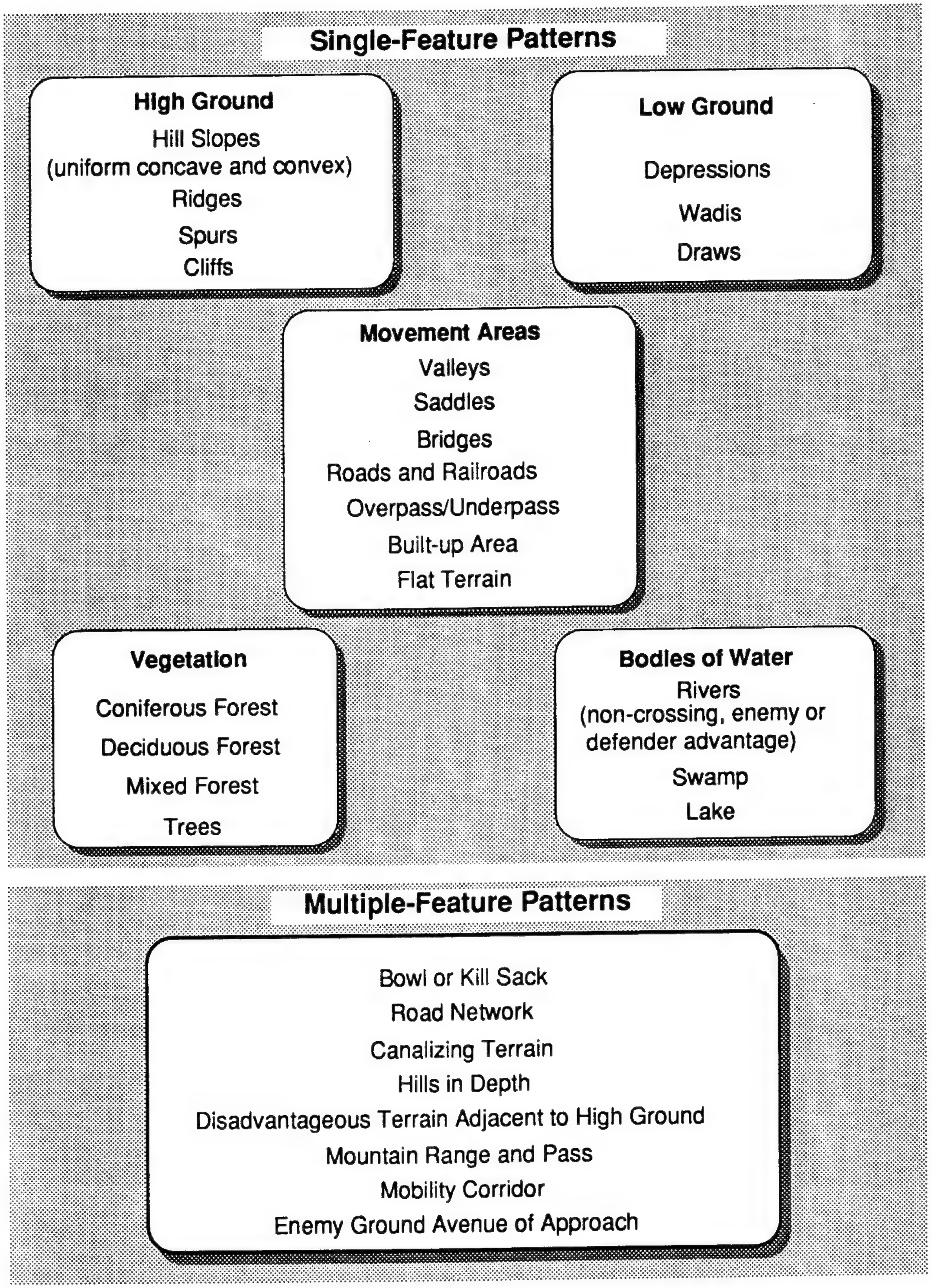


Figure 2. The 40 tactical terrain patterns included in the Pattern Recognition Training Course.

students to discriminate among different types of patterns, as well as generalize among varying instances of the same pattern type. The goal of the identification exercises were to develop a set of prototypical patterns as a result of repeated practice and experience

with varying instances of the same pattern category. Students identified several marked patterns per map by writing in the name of each pattern, as given in the student text, on an answer sheet. Feedback on each response (in the form of the correct answer) was provided on the reverse side of each map.

A3.1. Saddles (Enemy moves through saddle at roughly a 90 degree angle to the area occupied by the friendly forces)

General Definition: Saddles are a low area between two areas of higher ground. A saddle is not necessarily defined only as the low ground between two hill tops. It can also be a low area along an otherwise level ridgeline. Saddles by definition have low ground in two directions along one axis and high ground in two directions along the other axis.

Schematic:

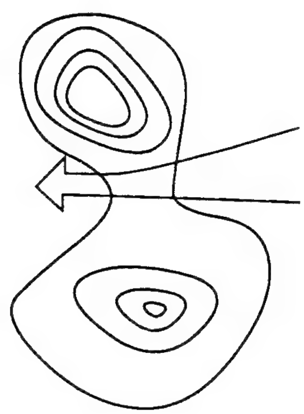


Figure 10. Saddle

Critical Features: Contour lines defining saddles are usually shaped like an hour glass, or the center, narrow section of a figure eight. Saddles are typically found between two hills, within hill masses, or within other high ground terrain features.

Military Significance: Saddles are militarily significant for two reasons:

(1) The "natural" avenue for crossing a ridgeline is at the saddle and at right angles to the ridgeline.

(2) Saddles, by definition, have low ground in two directions and high ground in two directions. This configuration provides natural defensive positions on the high ground against forces moving in the saddle.

Advantages: The high points of a saddle make good defensive positions that allow good fields of fire into the relatively canalized terrain below. The low point is a good position to place obstacles or mines.

Disadvantages: Grazing fire may be restricted if defensive positions are across from one another.

Figure 3. Pattern description of saddles from Student Text.

The second type of exercise in the workbook required students to analyze battalion sectors drawn on copies of 1:50,000 scale military topographic maps. In these "sector analysis" exercises, students were instructed to look for the militarily significant patterns contained within, or near, the boundaries of the sector. The training objective of this set of exercises was to teach students to *use* and *integrate* their newly developed pattern recognition skills with the information they had learned in the student text about the military significance of terrain patterns. The goal was to give the patterns their contextual meaning by showing students how they would be used in an actual battle situation. The task in the sector analysis exercises was straight forward. Students were instructed to box what they deemed to be the most militarily significant patterns on the map, write in the name of each pattern on an answer sheet, and briefly state the pattern's military significance. For the sector analysis exercises, feedback was provided for each sector on the reverse side of the map. Up to 10 possible responses, which included a marked terrain feature and a brief description of its military significance, was provided to the student. Note that the provision of an exhaustive list of all militarily significant terrain features in a battalion sector was not possible, nor could an exhaustive list of responses be expected from students. Therefore, an intermediate solution to this problem was to draw students' attention to those patterns that possessed the highest degree of significance.

The workbook was organized in five major sections: (1) an introduction, (2) 26 exercises in single-feature pattern identification, (3) 13 exercises in single-feature sector analysis, (4) 17 exercises in multiple-feature pattern identification, and (5) 11 multiple-feature sector analysis exercises. The identification exercises for single-feature patterns contained approximately 10 items per map (each map corresponds to a single exercise), producing a total of 263 identification items. For multiple-feature patterns, approximately four items were presented per map for a total of 60 identification items. In the sector analysis exercises, students were instructed to look for either single- or multiple-feature patterns, depending on the set of exercises being conducted. Figure 4 shows a typical single-feature identification exercise taken from the workbook. Figure 5 shows a typical multiple-feature sector analysis exercise. In each case, please note the feedback provided on the reverse side of the exercise, and the map feedback provided in Figure 6.

Roughly half of each set of exercises were copied in color, and half were black and white copies of military topographic maps. The workbook was bound in a 1 inch three-ring binder with tabs marking each major section. A variety of different types of terrain (e.g., hilly, mountainous, highly vegetated, desert, flat terrain, etc.) were included in each set of exercises to ensure that students were exposed to a wide variety of maps and terrain types, and learned to recognize terrain patterns despite perceptual variability within each category of pattern.

Response Book. The response booklet provided students with all of the maps and response sheets necessary to conduct the exercises contained in the workbook. Students were instructed not to write in the workbook. Instead, they were to write all of their answers and comments in the response booklet. A concerted effort was made to make the materials usable, which entailed the provision of page numbers on every page, the inclusion of tabs indicating sections, provision of the answer key in the

workbook so that the student could easily compare his or her answers in the response booklet with answers keys contained in the workbook, and ensuring that the orientation of the maps were the same in the workbook, answer keys, and response booklet.

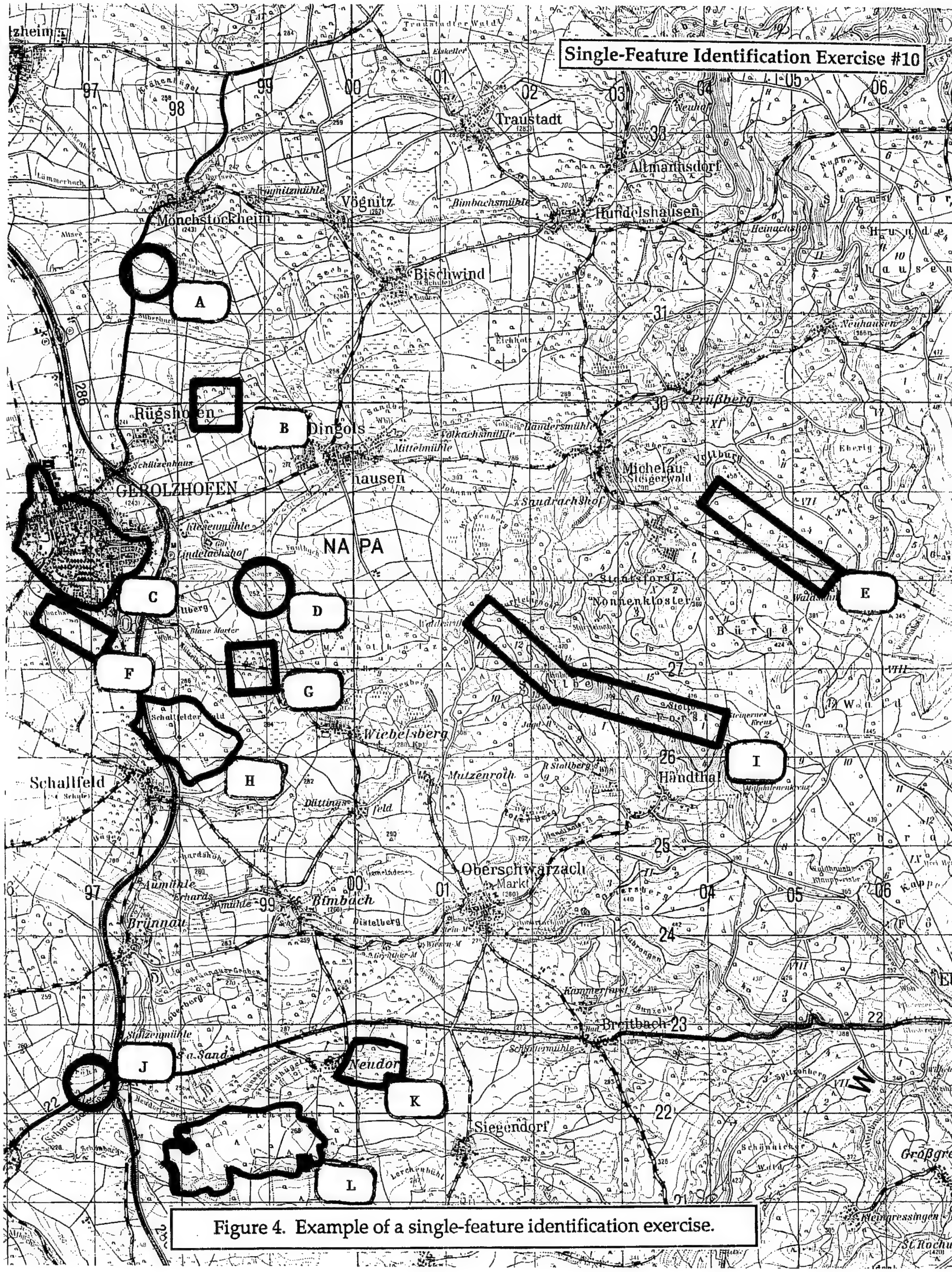


Figure 4. Example of a single-feature identification exercise.

Single-Feature Identification Exercise #10

ANSWER KEY

Pattern Letter	Pattern Name
A.	Lake
B.	Trees
C.	Built Up Area
D.	Lake
E.	Ridge
F.	Lakes
G.	Trees
H.	Deciduous Forest
I.	Ridge
J.	Overpass/Underpass
K.	Mixed Forest
L.	Mixed Forest

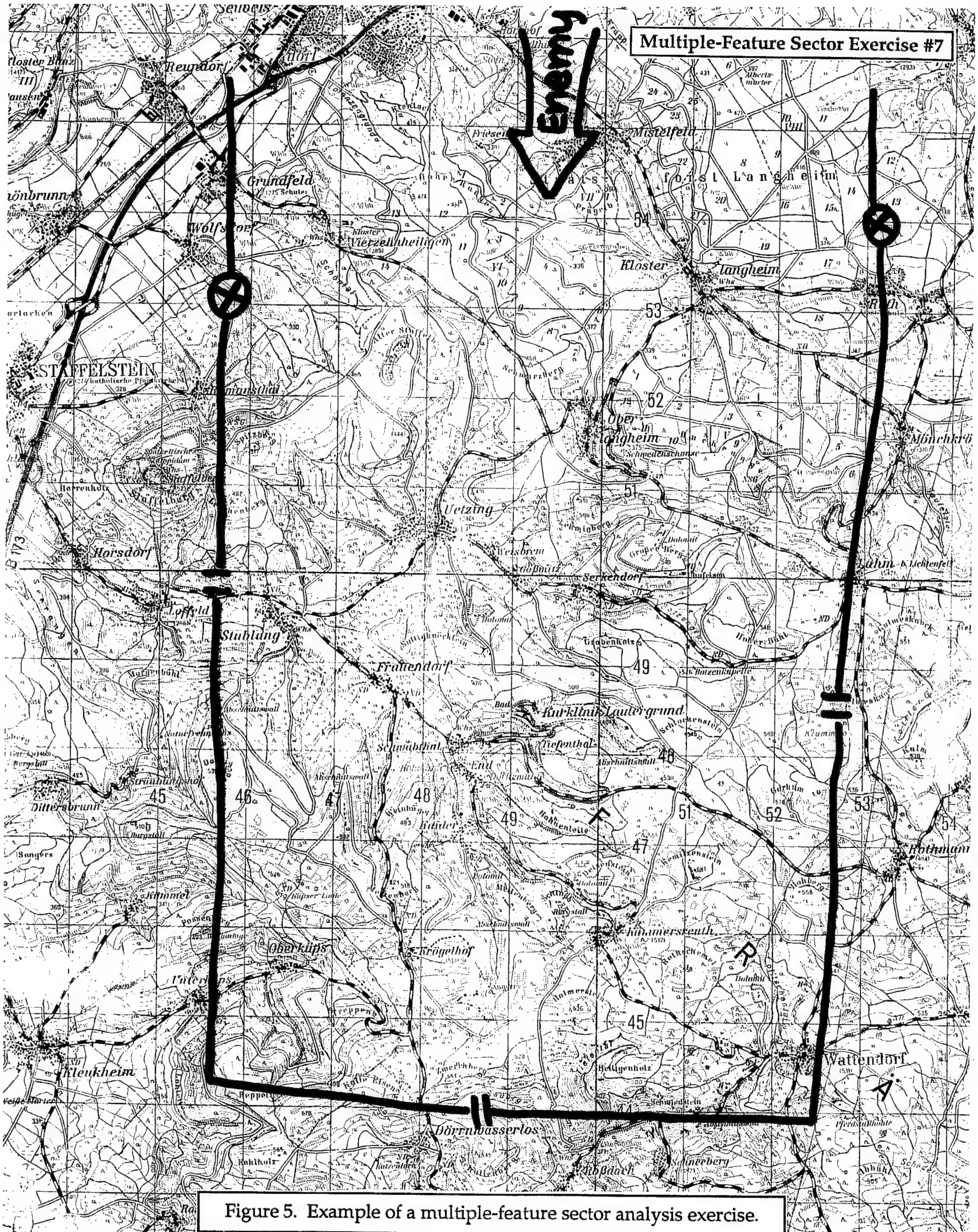


Figure 5. Example of a multiple-feature sector analysis exercise.

Multiple-Feature Sector Exercise #7

ANSWER KEY

(A) This series of hills will provide a defense of **hills in depth**. If the enemy succeeded in gaining access to the mobility corridor on the east, he would most likely move along the eastern border of the hills.

(B) The enemy would be severely constricted and **canalized** if he attempted to maneuver through this area. He would be canalized by the city of Oberlangheim and the surrounding high ground. The high ground also provides the defense the opportunity to capitalize on the enemy's disadvantage, making this area **disadvantageous terrain adjacent to high ground.** This area remains one of the few mobility corridors and avenues of approach for the enemy to maneuver through the sector.

(C) Troops that advance through this **disadvantageous terrain adjacent to high ground** will be **exposed** to observation and fire.

(D) Troop movement will be impeded and **canalized** in this **disadvantageous terrain adjacent to high ground**.

(E) The high ground surrounding this area will **canalize** the enemy in this area; the high ground can be employed by the defense to take advantage of the enemy's constriction, forming **disadvantageous terrain adjacent to high ground.**

(F) Troop movement will be constricted and severely **canalized** in this **disadvantageous terrain adjacent to high ground**.

(G) There is a good **road network** throughout the sector for logistics supply, lines of communication, and ingress and egress in the sector.

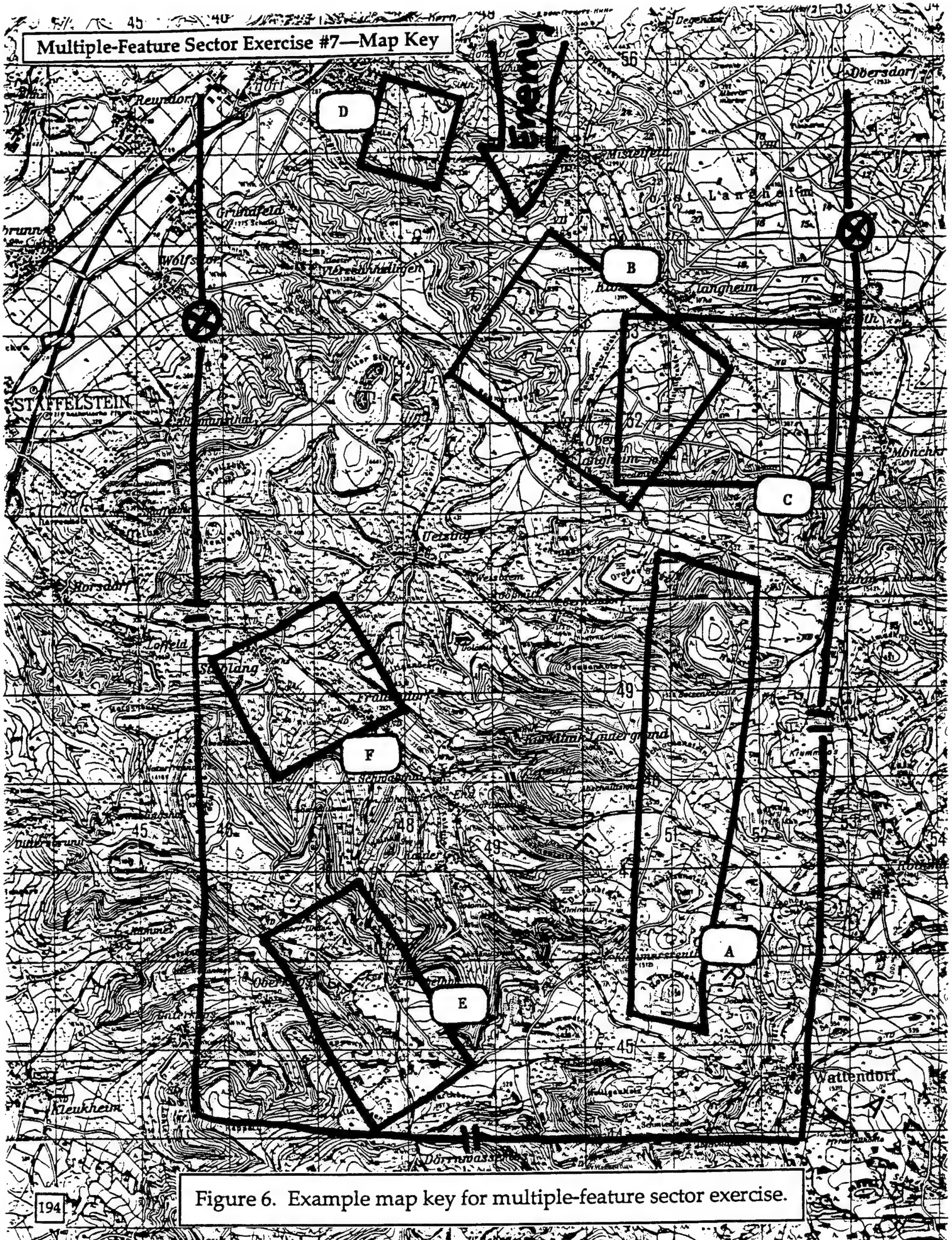


Figure 6. Example map key for multiple-feature sector exercise.

Method

Subjects

Eighty-three college Military Science students (69 males and 14 females) participated in this study as subjects. Four year groups (MS1-MS4) were sampled from student ROTC populations at the University of California at Santa Barbara, California State University San Bernardino, California Polytechnic University at Pomona, and Auburn University in Montgomery, Alabama. Thirteen students were in their first year of study, 18 in their second, 33 in their third and 17 students were MS4s. Thirty-seven of the Military Science students had previous military experience (2 MS1s, 4 MS2s, 20 MS3s, and 11 MS4s). Subjects participated as part of a course requirement. Sixteen individuals with prior service were assigned to the group that received pattern recognition training. Twenty-one were assigned to the control group.

Fourteen Army Captains from Ft. Bragg, North Carolina also participated as volunteer subjects. Each of the officers had completed Advanced Course training.

Materials

Course Materials. The course materials included three booklets: (1) a student text that contained defining information about a set of terrain patterns, (2) a workbook that contained four sets of pattern recognition exercises, and (3) a response booklet that students used in conjunction with the exercises contained in the workbook. Each of the three booklets are described in the previous section of this report.

Measurement Instruments. Four measurement instruments were developed to assess the knowledge and skills attained through the pattern recognition course. In a complementary fashion, the four instruments provided an assessment of (1) the amount of relevant material students learned through their education and training, (2) the amount of relevant material retained, and (3) students' ability to generalize their recognition skills to novel stimuli and novel tasks. The tests were also designed to provide an evaluation of specific course objectives, which included the effect of the pattern recognition training course on students' (1) knowledge of defining characteristics and military significance of battlefield terrain patterns, (2) ability to quickly and accurately identify individual terrain patterns on a map, (3) ability to analyze the military significance of a battalion sector of responsibility, and (4) knowledge structure or organization of battalion sectors. Care was taken to ensure that each measurement instrument was appropriate (i.e., sensible and comprehensible) to students who received the pattern recognition training, as well as students who had only received standard ROTC training.

Multiple Choice Test. As noted above, the four tests addressed the various assessment issues and course objectives in a complementary fashion. The primary objective of a 32-item multiple choice test was to assess the amount of knowledge subjects had attained through either their ROTC education, officer basic and advanced course, or the pattern recognition training. The Multiple Choice test was designed to measure knowledge of defining characteristics and military significance of common battlefield terrain patterns. Ten of the items in the test assessed students' knowledge of

the critical distinguishing features of terrain patterns and 17 items involved military significance. The remaining five items were designed to assess students' ability to correctly identify topographic representations of two dimensional perspective views of terrain (see Figure 8). As such, they represented an assessment subscale that measured the ability to generalize map reading skills beyond the specifics of ROTC or terrain pattern recognition training. The primary measure of performance for the multiple choice test was the number of items correctly answered. Subscales were also developed, relevant to (1) the defining characteristics of patterns, (2) the military significance of patterns, and (3) the ability to generalize from two-dimensional topographic map representations of terrain patterns to two-dimensional perspective views.

Speeded Identification Test. A measure of pattern recognition speed and accuracy was also developed and used to assess the effectiveness of the training. Figure 7 shows two example Speeded Identification items. One of the items requires the student to discriminate wadis from draws and intermittent streams. The second item examines the ability to identify bridges.

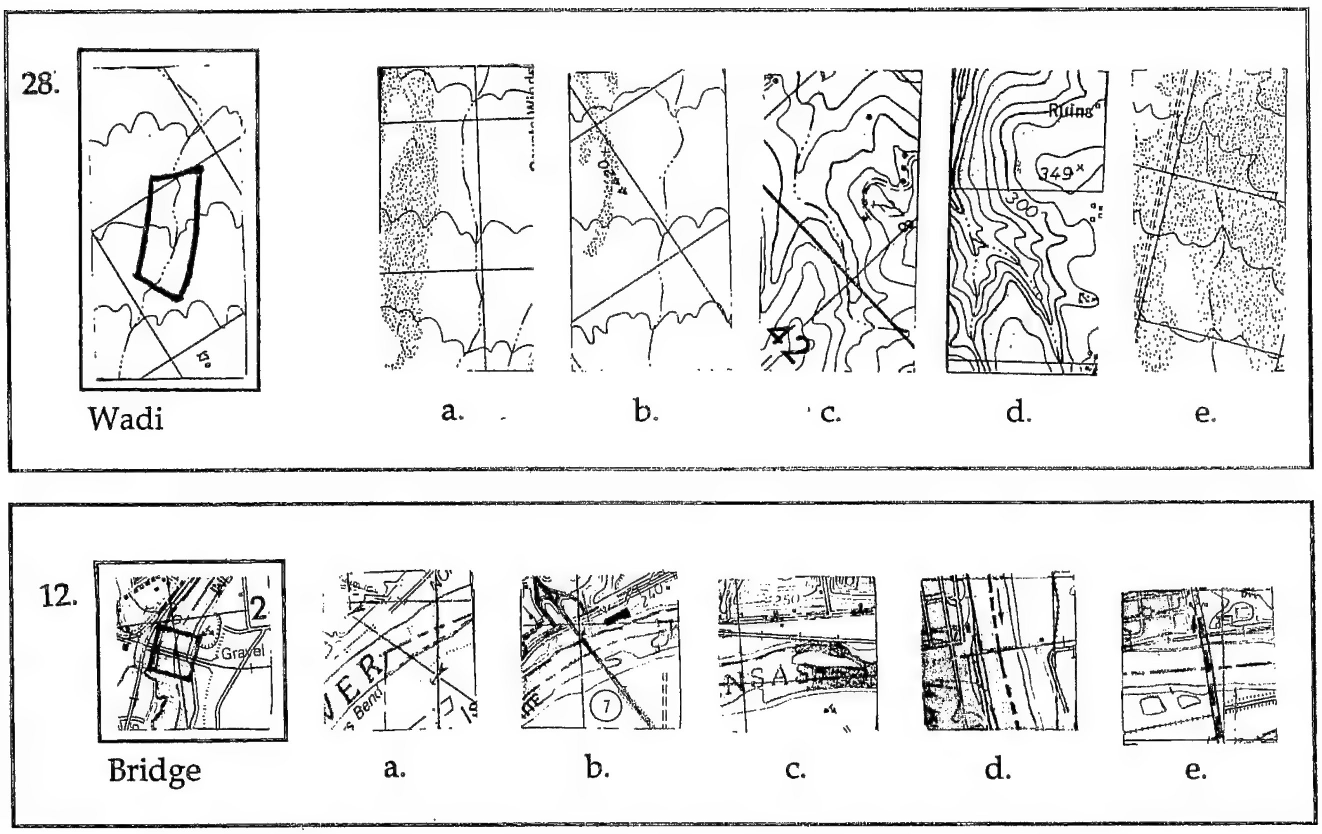
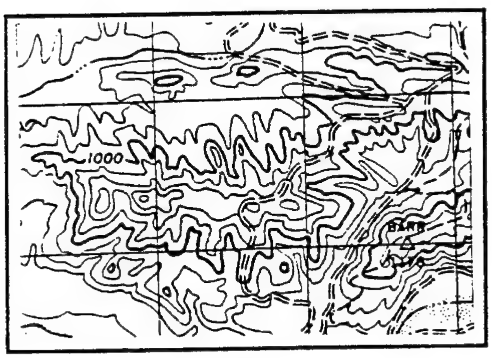


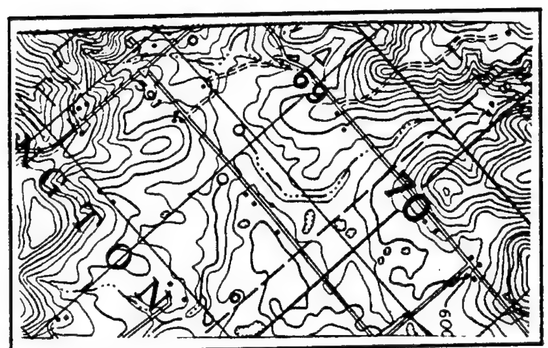
Figure 7. Example items taken from Speeded Identification Test.

Students were instructed to find and mark all of the terrain patterns that were the same type of pattern as a standard, which was the first pattern presented in each item. As shown in Figure 7, one standard and five options were presented per item, many of

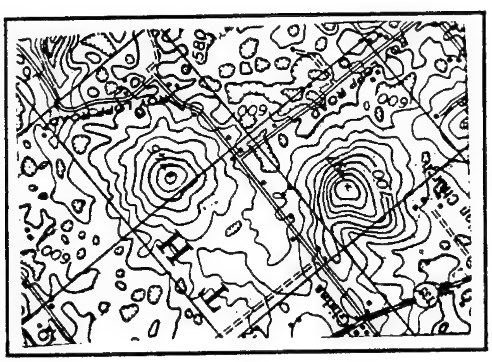
19.



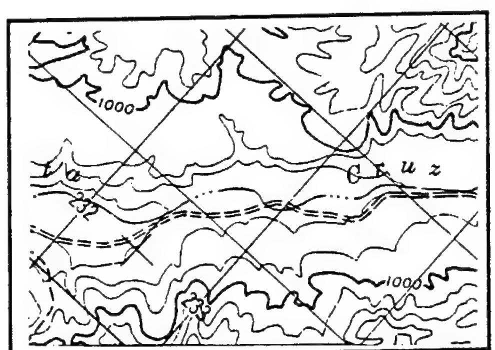
a.



b.



c.



d.

Figure 8. Example two-dimensional perspective item from the Multiple Choice test.

which contained more than one correct answer. Under each standard, the name of the pattern it depicted was provided to eliminate any ambiguity about the target feature. Twenty items tapped students' identification and discrimination skills in recognizing single-feature patterns, while the remaining nine were devoted to multiple-feature patterns. Nine items were presented in color and twenty were black and white copies

of topographically represented features. To assess the experimental group's perceptual generalization skills, the three single-feature patterns that were presented in black and white copies in the training (concave slope, spur, and saddle), were tested in color versions in this test.

Sector Memory Test. A third evaluation instrument used in this study measured students' memory for terrain configurations composing battalion level sectors. The assessment objective of this test was to determine whether individuals who had received pattern recognition training had superior memory for configurations of terrain features than subjects who had not received the training. It was hypothesized that one of the primary effects of pattern recognition training is a mental reorganization of the meaningful precepts contained in terrain, as is often evidenced by experts' tendency to recognize clusters or chunks of stimulus information (e.g., Simon & Chase, 1973). If this hypothesis is true, then patterns of recognition memory for constellations of terrain features should be affected by the reorganization. For example, students who receive pattern recognition training should have better memory for sectors that are perceptually similar but militarily different to previously seen sectors because their examination of sectors should be directed by the militarily significant terrain features.

Recognition memory for sectors was tested in two subtests, each of which involved a study and a testing phase. In the study phase, students were presented with a packet of photocopied 1:50,000 scale topographic maps. On each map a battalion sector had been drawn and the subjects' instructions were to simply study the sectors. In the testing phase, students were again presented with sectors drawn on 1:50,000 scale military maps, 40% of which had been in the original study set and 60% of which the subjects had never seen before. The task was to identify which sectors had been contained in the study set by writing "OLD" directly on the map, and which were new sectors by marking "NEW" on the map. Two memory tests were administered to the subjects. The first contained 20 items in the study set and in the test set, while the second test contained 13 items in both sets of stimuli.

The distracter items of the test sets (those that should have been marked NEW) fell into one of four categories relative to an original sector item from the memory set. The four categories were developed based on the degree to which the distracter item was (1) militarily similar and (2) perceptually similar to one of the memory set items. Hence, distracters were either militarily and perceptually similar, militarily similar but perceptually dissimilar, militarily dissimilar but perceptually similar, or militarily and perceptually dissimilar to a sector in the memory set. Sectors were deemed militarily similar if they had been classified into the same category of sector by an SME. The military categories were obtained and identified in a sorting exercise of sectors that was conducted for the purpose of developing the Sector Memory test. One of the SMEs who had provided assistance in the training development phase of this project (#1) was asked to sort 60 sectors into meaningful categories. Very little direction or instruction was given to the SME regarding the content or meaning of the categories. He was simply told to create categories that he himself found meaningful on the basis of similarities among the sectors assuming only that he was the commander of a battalion unit and his mission was to defend in sector. The SME produced six categories in his

sort based on several dimensions. The first of these dimensions was the degree to which the terrain provided natural boundaries along the flanks of the sector. The second dimension was the degree to which the terrain permitted enemy freedom of maneuver. On one end of this dimension, the enemy was severely canalized; on the other end, the enemy could maneuver where ever he wished. A third dimension was how trafficable the sector was to mounted forces due to extreme terrain or vegetation. The remaining three scales included the degree to which the terrain afforded enemy speed of movement, cover and concealment for the defense, and observation for the defense. The SME labeled his six categories of sectors in the following way.

Category 1. Sectors that could not be used for a mounted attack due to extreme terrain or vegetation.

Category 2. Sectors that have lateral boundaries reinforced by no/go terrain; but the attacker enjoys significant freedom of maneuver.

Category 3. Sectors that have significant canalization within the sector and some lateral boundary risk.

Category 4. Sectors in which the enemy has some freedom of maneuver, some no/go opportunities for the defense, and some lateral boundary risk.

Category 5. Sectors in which the attacker's movement is impeded by terrain throughout the sector. The terrain clearly favors the defense.

Category 6. Sectors in which the enemy has significant freedom of maneuver throughout the sector, there is limited terrain advantage for the defense, and considerable lateral boundary risk.

Sectors that were taken from the same map were regarded as perceptually similar because they represented identical topographies. The distracters were composed of equivalent numbers of sectors falling into each of the four categories of sector similarity.

Sector Analysis Test. The last of the four measurement instruments used in this study was a test in which students analyzed and evaluated battalion sectors. The assessment objective of the sector analysis test was to determine if the pattern recognition training produced a superior understanding of the military importance of terrain features. Of the four measurement instruments, the Sector Analysis Test provided the closest estimate of ultimate job performance. It required subjects to evaluate sectors and their terrain features presented on military topographic maps, which is similar to terrain analysis tasks performed in the field. Subjects' ability to apply global dimensions of evaluation to sectors was particularly emphasized in this test because this high level of analysis often serves as a marker of expertise in many domains. The global dimensions of sector evaluation used in this test were the degree to which sectors (1) provided flank protection for the defense, (2) provided they enemy with freedom of maneuver, and (3) the terrain favored the defense over the enemy. Three sectors drawn on black and white photocopies of 1:50,000 scale military maps were presented in the Sector Analysis

Test. For each sector, subjects were asked to provide a rating on a 5-point scale indicating their evaluation of the sector along the three dimensions mentioned above. Subject's marked or circled a number from 1 to 5 along the scale to indicate their response rating. For each dimension, subjects were also asked to justify the rating by describing the terrain features that contributed to their evaluation. The three sectors varied both militarily and in the type of terrain features they possessed. For example, two of the sectors had boundaries that were placed along untrafficable high ground, providing considerable natural flank protection for the defense, while the third sector's boundaries were almost completely open. Enemy maneuverability was severely restricted in one sector, moderately restricted in a second, and almost completely unrestricted in the third. One sector was taken from a map representing highly variable terrain with significant hills/mountains, one was from hilly and depression ridden territory near the Ohio River, and the third represented a relatively flat desert area of Arizona.

Procedure

Sampling and Assignment to Groups. Table 3 shows the assignment of subjects to experimental and control groups for each of the participating ROTC departments in California and Alabama. The numbers shown in Table 3 reflect the total ROTC enrollment for the participating schools, however, data for the thirteen students at Auburn University who received the training was dropped from the analyses because the researcher suspected that proper procedures were not followed with these students. Subjects were randomly assigned to the groups.

Table 3.
Subject Assignment to Control and Experimental Groups

		YEAR GROUP				
INSTITUTION	GROUP ASSIGNMENT	MS1	MS2	MS3	MS4	TOTALS
University of California	Received Training	2	6	6	3	17
	Control Group	3	3	6	1	13
Auburn University	Received Training	0	0	12	1	13
	Control Group	0	0	4	7	11
Ft. Bragg	Expert Comparison Group	n/a	n/a	n/a	n/a	14
Cal State San Bernardino	Received Training	2	2	0	2	6
	Control Group	2	1	1	0	4
Cal Poly Pomona	Received Training	2	3	3	3	11
	Control Group	2	3	1	2	8
	Totals	13	18	33	19	83/97

The Army officers who participated in this study volunteered their services during an umbrella[2] week offered at Ft. Bragg. These officers were all Captains who had attended their branch's Officers Advanced Course, and most were assigned as Company Commanders or battalion staff officers in combat or combat support battalions.

Training Procedure. The pattern recognition training was initiated with the distribution of course materials to each student in the experimental group at each of the four universities. The experimenter and/or the Professor of Military Science (PMS) distributed the materials to the students at one of their regularly scheduled lab courses or at a prearranged time. During this initial meeting, students were given instruction in the purpose of the training, the purpose of each course book, the use of the course materials, and the duration of training. The subjects were instructed to first read and study the student text before beginning work on the exercises contained in the workbook. They were also told to work through the exercises in the sequence in which they were presented. They were to complete the single-feature pattern identification exercises first, followed by the sector analysis exercises. After completing all of the single-feature exercises, they were to follow the same order of study for the multiple-feature patterns. (See Table 4 for sequence and estimated completion time of each set of exercises in the training.) The experimental subjects were allowed at least two weeks to study the student text and conduct the exercises in the workbook, at which time they were instructed to turn in their completed response booklets. At California Polytechnic University at Pomona and at California State University at San Bernardino, the study period was extended to three weeks.

The training received by the control group was the standard ROTC training. Students typically enroll in a land and navigation course in their second year of study, in which they receive instruction in map reading. Course materials often include a self-instructional text concerning fundamentals of map reading (SH 21-21) and the Army's field manual, *Map Reading and Land Navigation* (FM 21-26). Military Science students are also required to attend summer camp following their third year of study in which they must use maps to navigate. They also participate in numerous field exercises in which they use maps to navigate and identify their location.

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[2] Umbrella week is usually a one-week period of time each year when U.S. Army installations provide researchers, reporters, etc. the opportunity to talk to or collect data from soldiers.

Table 4.
Estimated Completion Time of Training Sequence by Task

Sequence	Study Task	# of Exercises in Task	Estimated Completion Time (Hours)
1	Read and Study Student Text	n/a	1-1/2
2	Identification Exercises for Single-Feature Patterns	26	2-1/4
3	Sector Analysis Exercises for Single-Feature Patterns	13	2
4	Identification Exercises for Multiple-Feature Patterns	17	1-1/2
5	Sector Analysis Exercises for Multiple-Feature Patterns	11	3/4
Total		67	8

Testing Procedure. Four learning outcome testing instruments and two individual difference measurement instruments were administered to the students. The control group completed each of the six tests with the exception of the University of California students, who completed only the four learning outcome testing instruments. Testing was completed in one session at each university. However, the sequence in which the tests were administrated was systematically varied to control for order effects. Students at Santa Barbara and San Bernardino first completed the four measurement instruments in the following order, (1) Speeded Identification test, (2) Sector Memory Tests (Set A followed by Set B), (3) Multiple Choice Exam, and (4) Sector Analysis test. Following completion of the four measurement instruments, the Paper Folding test of spatial ability and the Hidden Figures test of cognitive style were administered. The same tests were given to the students at Auburn University and Pomona; however, the sequence in which they were administered was counterbalanced. At Auburn University and Pomona, the measurement instruments tests were given in the first session in the following order, (1) Multiple Choice test, (2) Sector Analysis test, (3) Speeded Identification test, and (4) Sector Memory Tests (Set A followed by Set B). The Hidden Figures test was given first, followed by the Paper Folding test. Table 5 provides a listing of the test administration sequences and allotted times for each of the six tests for each Military Science department. The 14 officers at Ft. Bragg were administered only the four measurement instruments. They completed the tests in the order shown in Table 5.

Table 5.
Test Administration Sequence by University and Allotted Times

Measurement Instrument/Individual Difference Measure	Sequence # for UCSB and Cal State San Bernardino Administration	Sequence # for Auburn and Pomona Administration	Sequence # for Ft. Bragg Administration	Allotted Completion Time (minutes)
Speeded Identification	1	3	1	7
Sector Memory (Set A & B)	2	4	2	5, 4
Multiple Choice	3	1	3	20
Sector Analysis	4	2	4	20
Paper Folding	5	6	n/a	6
Hidden Figures	6	5	n/a	24

<u>Retest Procedure.</u> To determine if the knowledge and skills obtained through the pattern recognition course were retained over a nine-month period of time, a sample of subjects from the University of California at Santa Barbara were retested on three of the measurement instruments. Twelve subjects, six from the control group and six who had previously conducted the pattern recognition training were retested on parallel forms of the Multiple Choice, Speeded Identification, and Sector Analysis tests. The parallel forms of each test were created by modifying items. For the Multiple Choice test, approximately half of the 32 items were changed slightly by changing the options or stem. To ensure that the original and parallel form were similar in content, each item that was modified was changed in only a minimal way such that the item tapped the same type of knowledge. For example, instead of asking about concave slopes, the item was changed to tap knowledge of convex slopes. Because the Speeded Identification test is a speed test by nature, the parallel form was created by simply reordering the items. For the Sector Analysis test, three new sectors were created; the instructions, questions, and scales were kept the same as in the original version.

Results

Measurement Instrument Scoring and Reliability Estimates

The subject scores on the Multiple Choice, Speeded Identification, Sector Analysis, and Sector Memory tests were used to evaluate the hypotheses of interest in this study. The performance score for the multiple choice test was based on the number of items answered correctly. Subtest scores were also computed for the items designed to assess students' knowledge of the critical features and military significance of tactical terrain patterns. A third subtest score was computed for items that assessed the ability to match two dimensional perspective photographs of terrain features with two dimensional topographic map representations. The perspective subtest items were considered "novel" because they focused on a skill that was not included in the pattern recognition training. The Speeded Identification test was scored using a correction for guessing procedure. The scores were based on the number of options correctly identified minus a fraction (.25) of the number of items incorrectly identified. A subtest score was also computed for items that were presented in black and white in the pattern recognition training, but in color in the Speeded Identification Test. These subtest items assessed the ability to generalize perceptual/recognition skills to "novel" stimuli.

The scoring of the sector analysis test was somewhat more complex. First, three subject matter experts completed the three sector items of the test, providing their own responses in evaluation of the sectors. The SMEs' qualifications are shown in Table 2. A content analysis of their responses was conducted and a master list of acceptable answers was created. Subjects' scores were based on the comparison of their responses on the Sector Analysis test to the master list of SME responses. Students were given one point credit for each response they provided that matched an answer given by at least one of the SMEs. A total score for the Sector Memory test was then computed for each subject by summing all the points earned on each of the items. To determine the reliability of the scoring system for the Sector Analysis test, a second evaluator scored a sample of ten tests using the master list of SME responses. An Inter-rater reliability was then computed for the ten tests (r=.95), indicating a high level of reliability.

Sector Memory scoring was based on the number of correct identifications (OLD and NEW) provided by each subject. A Signal Detection analysis was also conducted. Hits, false alarms, misses, and correct rejections were computed for the two subtests. The two sets of scores were then combined into a single set of scores, which was then used to calculate a β rate and d' for each subject.

Reliability estimates were derived for each of the four measurement instruments. Split-half reliabilities were computed for the Multiple Choice test based on an odd/even split of the 32 items. Applying a Spearman-Brown[3] correction procedure for attenuation, $r = .85, p < .01$. Split half reliability estimates, corrected for attenuation, were also derived for the Sector Analysis and Speeded Identification tests based on an odd/even

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[3] See L. J. Cronbach's *Essentials of Psychological Testing* (1970) for a complete description of the Spearman-Brown correction formula for attenuation.

split of the questions, $r = .83$, $p < .01$ and $r = .96$, $p < .01$, respectively. Two separate estimates of the Sector Memory test reliability were computed; in both cases a Spearman-Brown correction procedure for attenuation was applied. The first estimate was based on separate assessments of d′ and β for the two subtests, $r = .13$, $p > .05$ and $r = .37$, $p < .05$, respectively. The second estimate was based on an odd/even split of all items collapsed across the two subtests, $r = .64$, $p < .05$.

Student scores on each of the four measurement instruments were used to test four hypotheses in this study: (1) terrain pattern recognition training increases the amount of information learned about terrain features compared to traditional Army training methods; (2) terrain pattern recognition training increases retention of information about terrain features; (3) terrain pattern recognition training produces better recognition of novel terrain features; and (4) individual differences in cognitive style and spatial ability mediate students' ability to profit from terrain pattern recognition training. The remainder of this results section is organized by the four hypotheses.

Analyses by Hypothesis

Hypothesis #1: *Pattern recognition training increases the amount of information learned about terrain features compared to traditional Army training methods.*

To test the first hypothesis, the experimental and control groups' scores on all four measurement instruments were submitted to a series of analyses. First, the scores from the Multiple Choice, Speeded Identification, Sector Analysis, and Sector Memory tests were submitted to a between-subjects two-way multivariate analysis of variance (MANOVA)[4] assessing the effects of training (Control vs. Experimental) and the effects of year group (MS1–MS4), which is tantamount to learning obtained through Military Science education alone. A single measure of performance was submitted for each of the tests (the number of correct identifications was submitted for the Sector Memory test). The use of a MANOVA procedure to evaluate Hypothesis #1, as opposed to four separate univariate analyses of variance (ANOVAs)[5], was adopted to control for experimenter-induced inflated alpha rates. The MANOVA revealed an overall effect of the pattern recognition training, multivariate $F(4,57) = 10.33$, $p < .001$, $\lambda = .580$. The univariate tests of the effect of group showed that the overall effect was produced for the Multiple Choice, Speeded Identification, and Sector Analysis tests, $F(1,60) = 25.28$, $p < .001$; $F(1,60) = 8.80$, $p < .01$; $F(1,60) = 20.94$, $p < .001$, respectively, but not for the Sector Memory test, $p > .05$[6]. The MANOVA revealed no effect of year, nor an interaction between year group and training. Figures 9a, b, and c depict the higher average performance

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4 For a complete description and explanation of the MANOVA statistical technique, see R.J. Harris, *A Primer of Multivariate Statistics* (1975).

5 For a complete description and explanation of the ANOVA statistical technique, see A. L. Edwards, *Experimental Design in Psychological Research* (1972).

6 An identical MANOVA was conducted using d′ and β rates for the Sector Memory test instead of the number of correct identifications, which also produced nonsignificant results.

scores on the Multiple Choice, Speeded Identification, and Sector Analysis tests, respectively. Figure 9d shows that this effect was not obtained for the Sector Memory test.

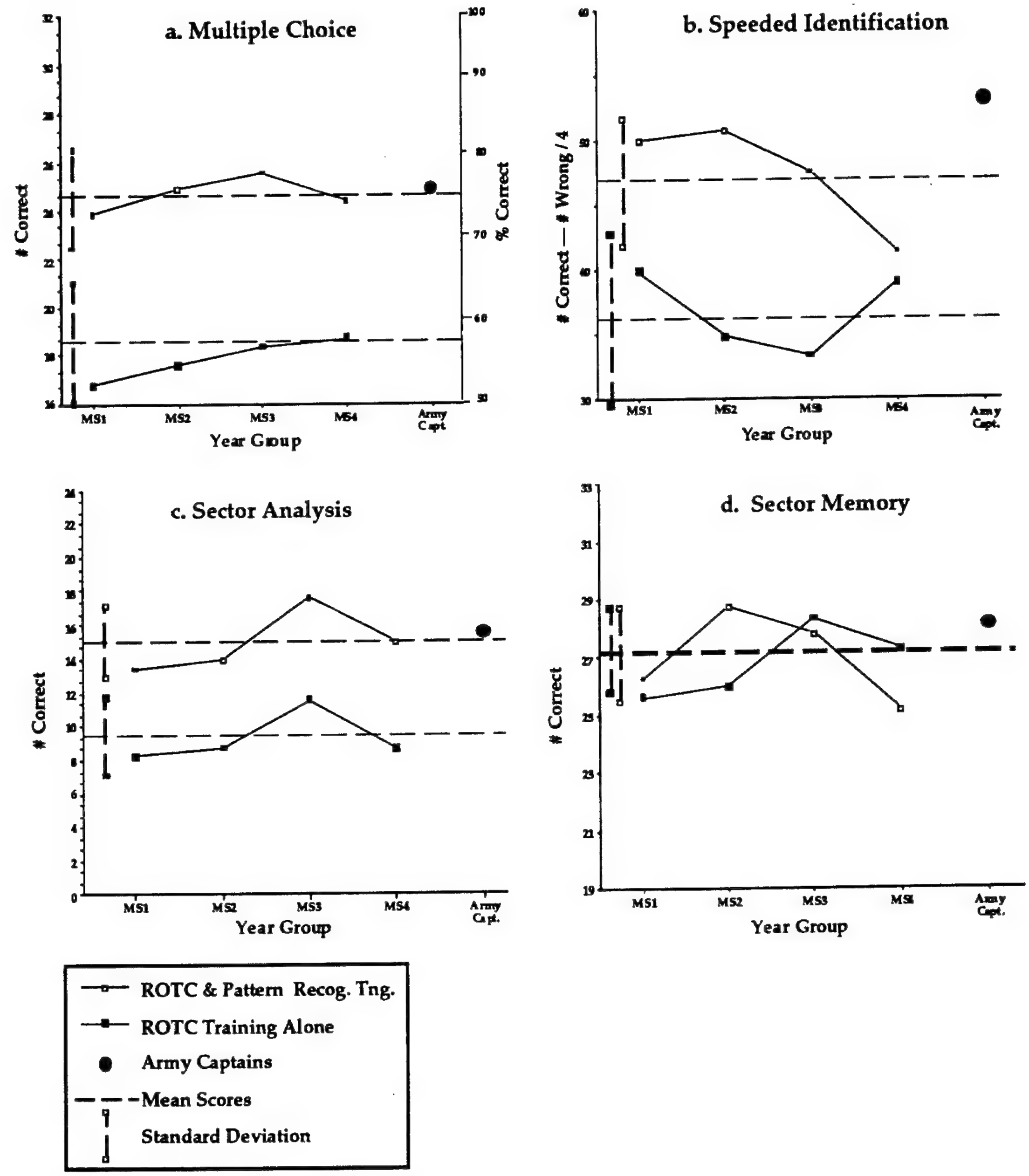

Figure 9. Mean scores on the Multiple Choice, Speeded Identification, Sector Analysis, and Sector Memory tests as a function of year group and training.

To determine if the control and experimental groups performed differently than did the more experienced Captains from Ft. Bragg, the mean scores for each student on the four tests were submitted to a one-way MANOVA comparing the three groups' performances. As obtained in the two-way MANOVA, an overall effect of group was obtained, multivariate $F(8,152) = 7.33$, $p < .001$, $\lambda = .521$ and the univariate tests indicated that the effect of group was limited to the Multiple Choice, Speeded Identification, and Sector Analysis tests, $F(2,79) = 19.14$, $p < .001$; $F(2,79) = 12.52$, $p < .01$; $F(2,79) = 11.93$,

$p < .001$, respectively. Post-hoc comparisons of the univariate analyses revealed that the Military Science students who did not receive the pattern recognition training scored lower than did the other students and the Army officers at Ft. Bragg. No differences were obtained between the students who completed the pattern recognition training and the Army officers. Figure 9 shows the average scores for each of the three groups.

A covariate MANOVA was also conducted to evaluate the potentially confounding effect of previous military experience. A 2 X 4 MANOVA compared the effects of training and year group with previous military experience as a covariate. The results were nearly identical to the two-way MANOVA reported above. An overall effect of the pattern recognition training was obtained, multivariate $F(4,53) = 8.86, p < .001, \lambda = .599$. The univariate tests of the effect of group showed that the overall effect was produced for the Multiple Choice, Speeded Identification, and Sector Analysis tests, $F(1,56) = 18.07, p < .001$; $F(1,56) = 9.83, p < .01$; $F(1,56) = 14.96, p < .001$, respectively, but not for the Sector Memory test, $p's > .05$. The MANOVA showed no effect of year on the four tests, nor an interaction between year group and training.

Hypothesis #2: Pattern recognition training increases retention of information.

To determine if the pattern recognition training improved retention of material learned, the students' scores from the first and second testing sessions on the Multiple Choice, Speeded Identification, and Sector Analysis tests were submitted to three two-way ANOVAs (one for each retest measurement instrument). These analysis compared the performances of the control and experimental groups on the original and retest sessions. Parallel forms of the Multiple Choice, Speeded Identification, and Sector Analysis tests were scored as in the original testing data. The ANOVAs for the Multiple Choice and Sector Analysis tests showed no overall effect of training, $p's > .05$. The analyses for these two tests also failed to reveal significant differences between the original test scores and the retest scores, nor an interaction between test session and type of training. In contrast, the ANOVA for the Speeded Identification test revealed an overall effect of group ($F(1,10) = 13.74, p < .01$) and a significant difference between the first and second testing sessions ($F(1,10) = 13.37, p < .01$, but no interaction. The mean score for the control group was 33.5, while the experimental mean score was 52.5. The first testing session produced an average score of 39.64; the second session mean was 52.16.

Hypothesis #3: Pattern recognition training produces better recognition of novel stimuli.

Two sets of data obtained in this study were pertinent to the question of generalization of learned skills to novel stimuli. First, the Multiple Choice test contained five items that tapped students' ability to match photographic depictions of terrain features with a corresponding topographic map representation. These items provided a test of students' ability to generalize beyond the pattern recognition training materials using skills they had obtained through the course. The second set of data was obtained from the Speeded Identification test in which several items presented terrain features in their color versions, when they had been presented solely in black and white in the training material. The terrain features that were assessed in the Speeded Identification tests were saddles, concave slopes, and spurs.

Students' mean scores on the five items of the multiple choice test that assessed their generalization skills were submitted to a two-way analysis of variance testing the effects of training and year group. No significant differences were observed between students who had received the training and those who had received only the standard ROTC education. No differences were observed between the four year groups, nor was the interaction between year group and training significant.

In contrast to the null results obtained in the novel items of the Multiple Choice test, the students who received the pattern recognition training performed better than the control group on the novel items of the Speeded Identification test. The students' mean scores on the subtest of black and white items were submitted to a two-way ANOVA comparing the effects of training and year group. Students who received the pattern recognition training correctly identified more items than did the control group, $F(1,61) = 11.68, p < .01$. The average score on the novel items was 4.63 (SD = 1.79) for the group that received the pattern recognition training out of a possible score of 6. In contrast, the control group produced an average score of 3.3 (SD = 1.12). No differences were observed between year groups and no interaction between year group and training was observed. It is important to note that the items that assessed the ability to generalize to novel stimuli were contained in the beginning of the Speeded Identification test. Therefore, these differences cannot be attributed to a failure to complete the test; only one subject failed to answer these items. The difference in the average scores of the two groups indicate that the students who received the pattern recognition training are generally superior at recognizing terrain features, independent of stimulus variation due to changes in color.

The mean scores on the black and white items of the Speeded Identification test were also submitted to a one-way ANOVA to determine if there were any differences in the scores among the student groups of subjects and the Army officers. The results of this analysis revealed an effect of group ($F(2,80) = 6.76$ $p < .01$), which was limited to a difference between the group that received the pattern recognition training and the control group. The Army Captains produced a mean score of 4.09, which was not different from either the control or experimental group means.

<u>Hypothesis #4:</u> *Individual differences in cognitive style and spatial ability mediate students' ability to profit from pattern recognition training.*

<u>*Cognitive Style.*</u> To assess the mediating effect of cognitive style, subjects were divided into two groups based on a median split of their scores on the Hidden Figures test. Table 6 shows the number of subjects who were classified as high or low scorers crossed by the number of subjects who received, or did not receive the pattern recognition training.[7]

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7 The overall N in Tables 5 and 6 is reduced because a number of students failed to complete the Hidden Figures and Paper folding tests when they left the testing session early.

Table 6.
Number of Students Who Scored Above or Below the Median Score on the Hidden Figures Test and Participated in the Pattern Recognition Course

	Below Median on Hidden Figures Test	Above Median on Hidden Figures Test	Totals
Received Pattern Recognition Training	16	18	34
Control Group	8	6	14
Totals	24	24	48

Subject scores on the four measurement instruments were submitted to a two-way MANOVA comparing the effects of training and cognitive style as measured by a median split of the Hidden figure test. The MANOVA revealed an overall effect of the training, as found in the previous analyses, $F(4,41) = 9.66$, $p < .001$, $\lambda = .515$. The univariate analyses showed that the effect of training was significant for each of the measurement instruments with the exception of the Sector Memory test, $F(1,44) = 26.32$, $p < .001$ for Multiple Choice; $F(1,44) = 9.54$, $p < .01$ for Speeded Identification; $F(1,44) = 24.11$, $p < .001$ for Sector Analysis. The results also indicated an overall effect of cognitive style $F(4,41) = 3.10$, $p < .05$, $\lambda = .767$. Univariate analyses indicated that the effect was limited to the Multiple Choice and Sector Analysis tests, $F(1,44) = 7.62$ $p < .01$ and $F(1,44) = 8.41$, $p < .01$, respectively. No interaction between cognitive style and training was observed. Figure 10 shows the effect of group and cognitive style on the mean scores from the Multiple Choice test and Sector Analysis test.

Simple correlations were computed to assess the degree of the relationship between performance on the Hidden Figures test and performance on the Multiple Choice and Sector Analysis tests. The results of these analyses revealed significant relationships among the two measures of performance and the scores on the Hidden Figures test, $r = .41$, $p < .01$; and $r = .46$, $p < .01$, respectively.

Spatial Ability. The potential mediating effect of spatial ability was also assessed by dividing subjects into two groups based on a median split of their scores on the Paper Folding test. Table 7 shows the number of subjects who were classified as high or low scorers crossed by the number of subjects who received, or did not receive the pattern recognition training.

Table 7.
Number of Students Who Scored Above or Below the Median Score on the Paper Folding Test and Participated in the Pattern Recognition Course.

	Below Median on Paper Folding	Above Median on Paper Folding	Totals
Received Pattern Recognition Training	16	19	35
Control Group	9	7	16
Totals	25	26	51

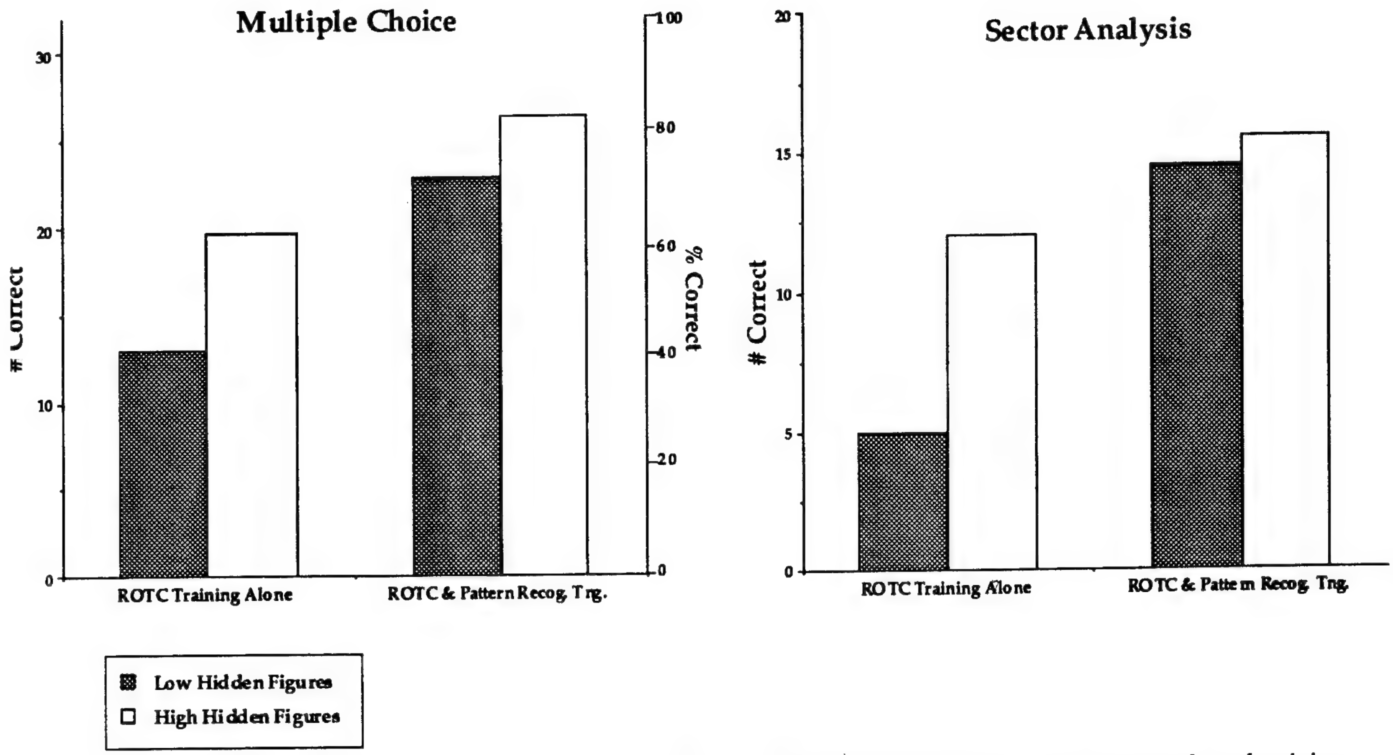

Figure 10. Mean scores on the Multiple Choice and Sector Analyses tests as a function of cognitive style and training.

Subject scores on the four measurement instruments were submitted to a two-way MANOVA comparing the effects of training and spatial ability as measured by a median split of the Paper Folding test. The MANOVA revealed an overall effect of the training; the students who received the pattern recognition training performed better than did the control group, $F(4,44) = 8.32, p < .001, \lambda = .569$. The univariate analyses showed that the effect of training was significant for each of the measurement instruments with the exception of the Sector Memory test, $F(1,47) = 21.04, p < .001$ for Multiple Choice; $F(1,47) = 12.66, p < .01$ for Speeded Identification; $F(1,47) = 16.61, p < .001$ for Sector Analysis. The results also indicated an overall effect of spatial ability, $F(4,44) = 3.04, p < .05, \lambda = .783$. Univariate analyses indicated that the effect was limited to the Speeded Identification test ($F(1,47) = 9.22$ $p < .01$), although the effect was marginal for the Multiple Choice and Sector Analysis tests, $F(1,47) = 3.81$ $p = .057$ and $F(1,47) = 3.41$ p

= .071, respectively. No interaction between spatial ability and training was observed. Figure 11 shows the effect of group and spatial ability on the mean scores of the Multiple Choice, Speeded Identification, and Sector Analysis tests.

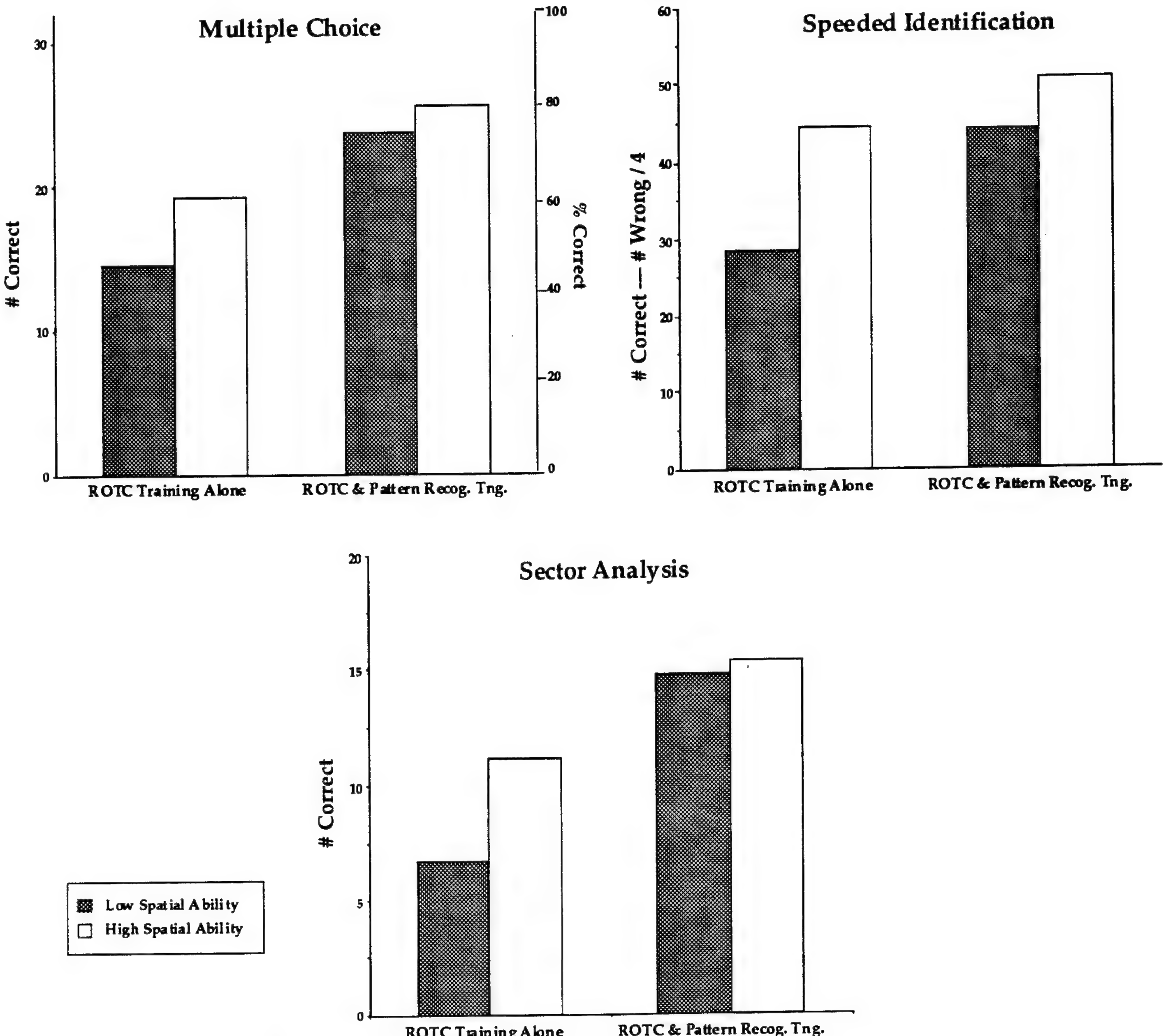

Figure 11. Mean Scores on the Multiple Choice, Speeded Identification, and Sector Analysis tests as a function of spatial ability and training.

Simple correlations were computed to assess the degree of the relationship between spatial ability and performance on the Multiple Choice, Speeded Identification, and Sector Analysis tests. The results of these analyses revealed significant relationships among each of the tests and the scores on the Paper Folding tests, $r = .56, p < .001$; $r = .55, p < .001$; and $r = .43, p < .01$, respectively.

Discussion

The superior performance produced by the ROTC students who took part in the pattern recognition training lends support to the hypothesis that this type of course work increases learning compared to traditional Army training methods. The robust differences obtained between the two student groups clearly indicate that the training produced superior learning compared to current ROTC education. Moreover, the pattern recognition training effectively raised ROTC student knowledge to a level comparable to Army Captains, who have completed both officer basic and advanced courses, and have several years of additional experience in field assignments. It is also important to point out that this effect was obtained for three out of the four measurement instruments employed in this study. The Multiple Choice test assessed students' comprehension of the military significance as well as the defining features of terrain patterns. The Speeded Identification test measured how quickly and accurately students could identify patterns. The test with the greatest face validity, Sector Analysis, was designed to determine if students could identify the most significant terrain features in a military sense, which is exactly what a commanding officer and his staff do in mission planning. Therefore, the effect of pattern recognition training was found in very different measures; some assessed knowledge, some assessed perceptual recognition speed, and some measured the interplay between knowledge and perceptual skill.

The lack of effects of any kind for the Sector Memory test is worthy of comment. This test was designed to tap changes in memory due to a reorganization of knowledge produced by the pattern recognition training. Unfortunately, it is likely that the test fell short of its objective. Anecdotal reports made by the students following the test indicate that they were using a test-taking strategy involving verbal information contained on the maps. For example, they memorized names of towns, rivers, and other features on the maps instead of evaluating the militarily significant patterns of the sectors. This strategy resulted in high performance levels for all examinees, and little variance. Consequently, no differences between the two training groups were observed on the Sector Memory test. A ceiling effect on this test prevented the accurate assessment of knowledge reorganization.

In contrast to the robust effect of training on the other three tests, students' year of ROTC study bore no relationship to their knowledge of terrain patterns nor their skill in recognizing and analyzing terrain features. We must conclude that students do not develop extensive terrain pattern recognition skills and knowledge during college Military Science schooling because there was no effect of year group on any of the performance measures used in this study, nor was there any interaction between year group and type of training.

One might argue that comparing the performance levels of students who receive standard ROTC training with those who receive additional pattern recognition training is unfair because the two programs have different learning objectives. If ROTC training does not incorporate the learning of tactical terrain patterns, it is not fair to evaluate students who receive only ROTC training on this skill. Examination of ROTC curricula and course materials reveals that the identification of terrain patterns is not

emphasized; however, it is certainly one component of the curricula. Students typically enroll in a land and navigation course in their second year of study, in which they receive instruction in map reading. Course materials often include a text, *The Fundamentals of Map Reading: A Self-Instructional Text* (SH 21-21, 1989, and the Army's Field Manual 21-26 (1993), *Map Reading and Land Navigation* . Military Science students are also required to attend summer camp following their third year of study in which they must use maps to navigate. They also participate in numerous field exercises in which they use maps to navigate and identify their location. Admittedly, the main thrust of the ROTC education with regard to maps is orientation and navigation, not terrain feature identification. However, feature identification is definitely one component of the education as evidenced by the test items in Figure 12 taken from a Midterm test given at one of the ROTC departments that participated in this study. Students who took this test were supposed to identify features contained on a particular map used in conjunction with the exam. Terrain pattern recognition is evidently at least one component of Military Science education, albeit one that is not given a great deal of emphasis. On the basis of the results of this study, it appears that students learn very little about identifying terrain features in their ROTC education. The lack of a year group effect is even more surprising when one considers many of the third and fourth year students had prior military experience. One would think that their greater experience alone would have resulted in better terrain recognition skills. Inclusion of prior service as a covariate in the analysis, however, failed to change any of the effects. Apparently, enlisted experience and ROTC education do not necessary result in a high level of terrain pattern recognition skills.

1. What does the symbol located at EH06470350 stand for?
2. What type of terrain feature is located at EG06109020?
3. What is located at EH11290291?
4. Match the list of terrain features with the numbered features in the diagram below.

   Fill _____
   Hilltop _____
   Ridge _____
   Valley _____
   Spur _____
   Cliff _____
   Draw _____
   Saddle _____
   Depression _____
   Cut _____

Figure 12. Terrain identification test items taken from a midterm administered in one ROTC program.

Compelling evidence was obtained that extensive pattern recognition skills and knowledge are learned sometime between the completion of ROTC education and completion of the Officer Advanced Course because students who took the pattern recognition training performed at a similar level on three of the four assessment measures to the Army Captains tested in this research. Unfortunately, when and how Army Captains develop their pattern recognition skills cannot be determined from this study. It may be that officers obtain their knowledge and skills in their Officer Basic course, field assignments, Advanced Course, or even independent study. To pinpoint the instruction, experience, or study that most effectively increases pattern recognition skills, it would be necessary to test officers before and after their Officer Basic course and before and after their Advanced Course. It is interesting to note that a ceiling effect was not observed for the Multiple Choice, Speeded Identification, or Sector Analysis tests, even for the more experienced Army Captains. Therefore, it is not clear whether pattern recognition skills continue to improve as one gains experience past the rank of Captain, or whether the Army Captains tested in this study exhibited the highest level currently obtained through Army training and experience. Examination of the terrain pattern recognition performance of Lt. Colonels would help to mark the development and importance of this skill.

A recent review of command and control research provides reason to hypothesize that there is room for improvement in Battle Command skills. Despite considerable resources devoted to training future commanders in the art and skill of command, field and laboratory studies have shown that current Battle Command performance is particularly weak in certain areas, including situation assessment (Fallesen, 1993). For example, errors in tactical decision making have been correlated with a failure to consider important information, verify unproven assumptions, assess the quality of information, and a poor ability to make predictions about battlefield events (Fallesen). Apparently, formal classroom training, practical experience in field exercises, and duty related experiences are not currently providing many officers with sufficient training in the area of situation assessment. One might hypothesize that junior officers might well benefit from additional pattern recognition training that focused on important elements of the battlefield. Further research is necessary to determine how and when officers achieve relatively skilled terrain recognition skills and if they continue to improve past the rank of Captain. Another issue of interest would be the effect of service branch. The Captains we tested were from Fort Bragg (Airborne); officers of the same rank in other disciplines of the Army may have developed better or worse terrain recognition skills.

The equivalent levels of performance between the experimental group and Army Captains also provides evidence of the validity of the three tests. The officers tested in this study had never seen the pattern recognition training materials and had no prior knowledge of this investigation. Their performance is solely based on their experience and training as Army officers. The argument that the tests assessed knowledge and skills that are pertinent only to the particular pattern recognition course developed for this study is therefore untenable. The measurement instruments developed for this project clearly assess skills pertinent to command.

In contrast to the robust effects of training found in this study, the results of our retesting of a small sample of subjects was mixed. In the Multiple Choice and Sector Analysis tests, no effect of training or session was obtained. Nor was an interaction effect between training and session observed. Apparently, subjects' scores on these two tests were approximately the same immediately following the pattern recognition training and nine months later. This finding provides evidence that the learning obtained from the pattern recognition course is stable over time. However, the lack of a difference between the group that received the pattern recognition course and the control group contradicts this interpretation of the data. If the learning is stable, then why do the two training groups perform at about the same level? The resolution of this problem is apparent by examination of the mean scores of the subsample of control group subjects. Apparently, the particular sample of control subjects obtained for the retesting not only scored quite well in the retest session ($M = 21.17$ for the Multiple Choice test and $M = 13.17$ for the Sector Analysis test), but also scored above its group mean in the original testing session ($M = 21.0$ for the Multiple Choice test and $M = 13.33$ for the Sector Analysis test). The means for the entire sample of control group subjects for the original testing session for these two tests were approximately 15.0 and 9.0, respectively. In contrast, the group means for the experimental group in the original testing session are comparable to those obtained in the retest session. Apparently, the particular subsample of control group subjects tested in the second session were the high performers of their group, at least for the Multiple Choice and Sector Analysis tests.

The results of the retention analysis for the Speeded Identification test were quite different from the results obtained with the other two tests. The group that received the pattern recognition training outperformed the group that received only the standard Army ROTC education. Apparently students who receive pattern recognition training are quicker and more accurate at identifying terrain patterns, even nine months after training. The results of this test also indicate that both groups of subjects improved their performance on the second session. This finding suggests that the test itself may have produced a learning effect. The fact that students from both groups scored better on the second testing session (no interaction was observed between training and testing session) indicates either that both groups learned from the test or that they were all exposed to additional learning in the interim between testing sessions.

The validity of the retention findings is worthy of consideration. Based on the lack of group differences in the Multiple Choice and Sector Analysis tests, one might conclude that these skills are lost after a period of time. However, adopting that conclusion would be a serious mistake. Retesting based on 12 subjects (6 control and 6 experimental) is truly inadequate to test the retention hypothesis. The findings we note above suggest that performance levels were maintained for both groups. However, the sample of control group subjects we obtained were clearly not representative of the control group that was originally tested. The results at this point are inconclusive with regard to retention of knowledge and skills; a larger sample of retest subjects is necessary to determine if the higher performance levels in the group that received pattern recognition training are maintained over time.

The results of this study were mixed regarding the degree to which pattern recognition training produces better recognition of novel stimuli. As measured by the 2D perspective subtest items of the Multiple Choice test, students who received the pattern recognition training did no better than the control group of subjects. The experienced group of officers also performed at a level comparable to the control and experimental groups, with each group correctly answering an average of approximately 3 out of the 5 items. Pattern recognition training, as defined in this study, does not apparently improve an individual's ability to make mental transformations between two and three dimensional terrain representations. However, the fact that the experienced group of Army officers performed at the same level as did the student groups suggests that the items themselves do not tap knowledge that is a component with expertise, at least at the rank of Captain. If the ability to make mental transformations between perspective views and topographic map representations is a marker of extensive experience, it may be that it is developed after an officer achieves the rank of Captain. Alternatively, there is reason to believe that it is an individual difference variable that is particularly resistant to improvement (Rogers & Cross, 1978, 1980; Cross, Rugge, & Thorndyke, 1982). This research has indicated that many Army aviators who are "experts" in land navigation are quite poor in this type of mental processing. When asked to determine their location on a topographic map given a perspective view, many subjects were generally unable to correctly identify their placement. However, some subjects were exceptionally good performers. It may be, then, that the ability to make mental transformations between perspective views and topographic representations is particularly subject to individual differences and resistant to change with experience. If this is true, pattern recognition training is unlikely to have an effect on this type of skill.

The effectiveness of pattern recognition training for training this type of mental process would depend on the strategy taken while analyzing the item. One strategy might be classifying each of the features represented by topographic maps into their respective terrain pattern categories. The individual might then choose the multiple choice option that matched the identity of the pictured feature based on their classifications. This strategy would only work for items that required discrimination of differing terrain features. It would not work for an item that presented topographic depictions of four hills as options to be matched with a picture of a hill, for example. Another strategy would involve more detailed analysis of subfeatures of a pictured terrain pattern. Pattern recognition training would not benefit performance if one were to take this second strategy because the strategy is not based on classification of the item. However, this would be the only strategy that would work if the options were all of one terrain category as in the example of hills described above. It is also a more cautious strategy because it involves a series of detailed comparisons between a picture of a terrain feature and multiple possible topographic representations of that feature. It is possible that the type of items contained in the Multiple Choice test elicited the more cautious type of strategy described above. The issue of strategy in two dimensional/perspective items could be investigated by systematically varying the type of training received by students and the type of items in a test. The test might contain items that required analysis by subfeatures as well as items that could be immediately answered by simple identification of terrain patterns. One would expect that individuals who received

pattern recognition training would perform better on the pattern based items, but about the same as the control group on the items requiring more analysis. If this effect was obtained, protocol analysis conducted as subjects explained their reasoning as they completed items would serve to further test the strategy hypothesis.

The degree to which pattern recognition training produced better recognition of novel stimuli was also assessed in the Speeded Identification test. Here, items presented in black and white in the training were presented in color in the test. Therefore, those individuals who received the training had never analyzed color versions of saddles, concave hills, or spurs in the context of the pattern recognition training, but were asked to rapidly identify these features in the test. Despite the relative novelty of these items on the Speeded Identification test, the experimental group of subjects maintained their superior performance on this subtest over the control group. Therefore, it appears that pattern recognition skills can generalize to novel perceptual experiences. This finding cannot be attributed to the control groups' failure to complete the test because the relevant items were some of the first items students completed in the exam. Only one subject from the control group failed to complete the relevant items.

Further research into this issue should address various types of processing and modifications to perceptual aspects of a stimulus to determine the limits of generalization. For example, would skilled performance still be obtained when pattern prototypes are distorted to varying degrees. How much could a pattern be perceptually modified and still be quickly recognized? Systematic variation in pattern degradation along several dimensions (color, shape, size, format) could be presented to subjects who received pattern recognition training and those who did not. This type of investigation would serve to determine the degree to which patterns can be modified and still be recognized by individuals receiving different types of training. It would also identify the dimensions that are amenable to generalization and potential interactions between training type and dimension. For example, it may be that individuals who receive pattern recognition training can easily generalize to variations in color, but not in shape.

The hypothesis that cognitive style would interact with type of training was not supported in this study. Independent of the type of training, individuals who scored above the median on the Hidden Figures test performed better on the Multiple Choice and Sector Analysis tests. However, they performed at about the same level on the Speeded Identification and Sector Memory tests. The most likely explanation for this finding is that individuals that are field independent (high scorers) tend to be more analytical and, hence, do better on tests requiring analytic ability. It may not be learning that is mediated by the field dependent/independent dimension, but test performance. Regardless, the capacity to profit from pattern recognition training does not appear to be related to field dependency.

Similarly, the capacity to profit from pattern recognition training is not related to spatial ability. The lack of an interaction between training and spatial ability indicates that this particular individual difference does not mediate learning from pattern recognition training. However, a general effect of spatial ability on the Speeded Identification test was observed. In fact, the effect of spatial ability is quite complementary to the effects of field dependency with regard to the tests that they affected. The overall effect

of spatial ability was limited to the Speeded Identification test, while the effects of field dependency were limited to the two tests of knowledge, Multiple Choice and Sector Analysis. The measurement instrument used to assess spatial ability, the Paper Folding test, is a measure of spatial visualization, which one might expect to be related to the ability to rapidly identify representations of spatial stimuli, such as terrain features. This type of test does not require analytic ability as much as it does quick perceptual decisions. Therefore, the relationship between spatial ability and performance on the Speeded Identification test seems reasonable.

Before concluding this discussion, we return to issues presented in the introduction of this report. Specifically, is pattern recognition skill a component of Battle Command expertise and if so, what type of pattern knowledge distinguishes experts from novices? The evidence suggests that pattern recognition of at least some components of the battlefield situation form the basis for situation assessment. As indicated by the Command Estimate, situation assessment is a critical element of Battle Command. It follows that pattern recognition skills are important to effective Battle Command performance. However, it is too early to conclude that pattern recognition is a *marker* of Battle Command expertise that distinguishes novices from highly experienced commanders. Through our knowledge elicitation sessions we have provided evidence that pattern recognition knowledge is necessary, but not sufficient to Battle Command expertise. Further research with more experienced officers would be necessary to identify characteristics that mark the development of expertise, and whether or not pattern recognition skills are an integral part of that development.

To assess the development of expertise, it would be important to determine whether the skills taught in the terrain pattern recognition course are an important part of the skills of a higher ranking officer. The measures of pattern recognition skills developed for this study could be used to assess the skills of higher ranking officers to provide this assessment. It is quite possible, and some of our evidence suggests, that Battle Command experts develop other pattern recognition skills not presented in the current training. We obtained evidence of larger meaningful patterns in the sorting exercise conducted with one of the SMEs who participated in this study. This particular SME had extensive experience; he was a recently retired Lt. Colonel who had served as an instructor at the Tactical Commanders Development Course at Ft. Leavenworth, Kansas, in addition to other command assignments. In the sorting exercise, we obtained evidence that this particular officer evaluated battalion level sectors along several dimensions: (1) the degree to which terrain provides natural boundaries along the flanks of the sector, (2) enemy freedom of maneuver, (3) trafficability to mounted forces due to extreme terrain or vegetation, (4) enemy speed of movement, (5) cover and concealment for the defense, and (6) observation for the defense. The SME also easily categorized the sectors he regarded as similar into groups, indicating that at least one large component of the battlefield situation can be readily classified. Although we were unable to obtain evidence that the entire battlefield situation could be conceived as a pattern, the terrain itself is classifiable and could constitute a pattern.

The classifications made by the SME could easily be taught as patterns of terrain. Moreover, the classifications can be easily related to several principles of warfare, which

are commonly taught in Army training and discussed in doctrine. For example, several of the dimensions identified by the SME were related to the principle of massing forces. If sector boundaries are naturally protected by no/go terrain, for example, then massing one's forces becomes an easier task. One does not have to distribute forces over the entire sector, or predict where the enemy will attack. He simply has to cover those relatively limited areas in which the enemy can maneuver. Hence, the patterns that the SME recognized were easily related to the rules, doctrine, and principles he had learned in his Army career through direct instruction. As an instructor at TCDC, he noticed that many of the students would benefit from training that instilled a better understanding of warfare principles such as massing. Perhaps pattern recognition training would assist their comprehension of important principles. Before development of such a course, however, it would be necessary to validate the findings obtained with this one SME. An important study would be to conduct a similar knowledge elicitation study with several officers at the Lt. Colonel rank to determine if they also use similar dimensions of evaluation when looking at sectors of responsibility.

Did we find the patterns that discriminate experts from novices? It is unlikely that the particular terrain patterns we trained form the basis for situation assessment expertise. However, because we did not obtain a ceiling effect on any of the measurement instruments, we cannot rule out the contribution of terrain pattern recognition at the level presented in our training. The Captains we tested did not perform at such a high level that one would think they had obtained the highest degree of expertise. As we mentioned above, it would be important to assess other higher ranking officers from other branches of the Army to make this determination.

Summary and Conclusions

The pattern recognition training developed for this project produces greater learning of battlefield terrain patterns than current Army ROTC training methods. Students who participated in the training knew more information about the critical features and military significance of terrain patterns than students who received standard Army ROTC education. They also were quicker at identifying terrain patterns and were better able to analyze battalion level sectors of responsibility. These results hold promise for pattern recognition training in general, suggesting that this type of training has the capacity to efficiently produce high levels of performance in a minimal amount of time. Greater research is needed to identify additional areas of Battle Command in which pattern recognition training might be beneficial.

The results of this study also suggest that the knowledge and skills obtained from pattern recognition training may be durable; however, the findings were inconclusive. Although the average scores obtained immediately following the training and nine months later were approximately the same, no differences between the two groups (pattern recognition training versus ROTC training alone) were observed in the second session. The lack of a group difference in the second testing session is most likely due to a sampling problem, as evidenced by the increased average scores in the control group.

Pattern recognition training can improve generalization of recognition skills to novel stimuli. However, generalizability may be limited to stimuli and processes that are different in some dimensions, but not others. The results of this study show that students who take pattern recognition training can easily transfer their skills to stimuli that vary in color. However, they were not able to perform related but different tasks such as matching topographic map representations with photographic perspective views of terrain.

Finally, pattern recognition training is apparently equally effective for various levels of spatial ability and types of cognitive styles. Individuals of high and low spatial ability and field independent and dependent cognitive style benefit equally from pattern recognition training.

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